THE BRIDGE SERIES

POWER AND PROGRESS

by

G. C. THORNLEY

General Editor

J. A. BRIGHT

The Bridge Series

POWER AND PROGRESS

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POWER AND PROGRESS

by

G. C. THORNLEY, Ph.D., M.A.

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General Editor: J. A. Bright

Its Aim and Purpose

The average student who has completed a simplified course of English has a vocabulary of about two thousand headwords, some familiarity with simple English syntax in shortish sentences, and a very limited acquaintance with English thought and ways of life. With this equipment or something very like it, he is usually invited to plunge into the largely uncharted seas of full English, to read books written specifically for an English audience assuming a full knowledge of English life and manners, complete familiarity with the most complex syntax, and a recognition vocabulary of at least ten and possibly twenty thousand words. It is no wonder if he becomes discouraged at the gap between what he knows and what he sees he has to learn. It is to help in closing this gap that The Bridge Series has been planned.

The student's troubles at this level are of three kinds, difficulties due to ignorance of background, difficulties of structure and difficulties of vocabulary. Difficulties of background can never be completely eliminated, but by careful choice of book and by annotation where difficulties are known to exist they have been to some extent minimized. Difficulties of understanding complicated sentences and slightly involved syntactical constructions can only be overcome by practice in reading them unhampered by

irrelevant difficulties of vocabulary. The syntactical structures of these books are therefore those of the original writers. This is not only advantageous because it gives useful practice in understanding more advanced structures, but also because it makes it possible to keep the original flavour of a book and a great deal of its literary value.

It is the difficulties of vocabulary that can be vigorously dealt with. Here we take it for granted that the student will know the vocabulary of simplified English (the words in *A General Service List of English Words*, Longmans 1953, containing the General Service List of the Carnegie Interim Report on Vocabulary Selection, and, where they differ, the first three thousand words in Thorndike and Lorge's *A Teachers' Handbook of Thirty Thousand Words*, Columbia University 1944). The words outside that vocabulary are defined within the simplified vocabulary in a glossary.

We also believe that the student should meet common words before rare ones. For example we keep in words like *affectionate, arouse, blunt, compliment, humour*, but we eliminate words like *sequestered, imputation, quondam, incoherent, demeanour* and *laudatory*. This is not because they are not useful words, but because someone with a vocabulary of two or three thousand words has many thousands of more common and therefore more useful words to learn before he comes to these comparative rarities. This elimination is done empirically on the basis of experience and common sense and also by the aid of Thorndike's list. The aim has been to get rid of all words outside the commonest seven thousand unless there was some obvious reason for keeping them. The territory of the series may therefore be broadly defined as starting from the three thousand word level and includes new words (suitably glossed) up to a seven thousand word ceiling.

Another important feature is that new words are evenly spread throughout the books, and therefore the reader does not come across a discouraging multitude of strangers in the first chapter. Words outside simplified English (unless they have appeared earlier in the book) are not introduced at a greater density than twenty-five per thousand running words of text—a density that experience has shown to be consistent with enjoyable reading. These new words, moreover, are not printed in black type or indicated in any other way because such indications lead to an undesirable concentration on the words rather than the sense, help to isolate words from the context in which they should be learnt, and above all discourage the reader from attempting to infer the meanings of unknown words either from the context or from his knowledge of related words. Skill in inference is one of the most important things to develop at this level.

The final assumption of the series is that after a diet of simplified English the student would like something with plenty of meat in it, and the greatest care is therefore taken to preserve everything possible of the vigour of the original, if the book is a simplification; or to give the reader plenty to think about, if the book is an original one.

Summing up, we can say that the books in The Bridge Series are of intermediate difficulty between simplified and full English. They contain little of vocabulary or idiom that is not immediately valuable, and we hope they will prove thoroughly enjoyable to read and study for their own sakes.

J.A.B.

FOREWORD

FOREIGN students of science, in many cases, learn English as a second language. It is for them that this book has been written. The aim of the book is not to teach science, but to introduce such students to the use of scientific words and expressions in English. It will, I hope, provide a stepping-stone for them to the harder task of reading unsimplified English books on their own subjects.

The first word of the title refers chiefly to the articles on coal and oil, which are discussed mainly from a present-day standpoint; but other sources of power are mentioned in the book. In the other articles, except the last, an attempt has been made to give a skeleton history of the progress of the science, or to compare the old and the new. In the last chapter, my indebtedness to H. G. Wells, which I here acknowledge, will be evident: it would probably be impossible to write of the future without being influenced to some extent by "The Sleeper Awakes."

G.C.T.

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CHAPTER I

Coal

THERE are many people in the world who seldom see a piece of coal because they live in a warm climate. But even if they never use coal personally, their lives are affected by it in countless ways. The importance of coal is not very apparent to those who rarely see it. They manage to get on well enough without it, and perhaps wonder why the rest of the world cannot do the same. It is difficult for them to understand why a shortage of coal should be so disastrous to the whole world.

Very little thought, however, will convince them of the importance of coal, and show them why, in manufacturing countries, a shortage of it is a national disaster. In most countries of the world coal is still the chief source of power. Trains run on coal; one load of coal will take a heavy train a long way. A small lump of coal gives off a surprising amount of heat.

But coal does far more for each of us than supply the necessary heat to move our trains. Almost everything around us has some connection with coal. Much of the food we eat has been transported either by steamship or by train, perhaps by both. Most ships are still driven by coal. Every bit of metal in sight, the nib of a pen, the frame of a desk, the pin in a coat, the telegraph wire outside in the street, was once molten metal running out of a furnace heated by coal.

The electric power that turns the wheels of industry is,

in most cases, coal power in another form. It is usually coal that drives the dynamos which produce the electricity. Power cannot be created out of nothing, and all the electric power used to-day was originally either water power, oil power or coal power; and most of it was coal power.

Coal has a nickname. It is called "Black diamonds," not because, like diamonds, it is mostly carbon, but because it is as valuable as diamonds. We could easily do without diamonds, but we could not do without coal.

* * * * * * *

After the last great war there was a shortage of coal in Europe. In the Ruhr, the industrial heart of Germany and of Europe, great damage had been done. Whole towns had been destroyed by bombing and many of the coal mines had been extensively damaged, especially the buildings and machinery above the ground. Many of the miners had gone into the army; thousands were prisoners of war, and thousands would never return home. The mines were restarted, but for many months the output of coal was very low and it was not sufficient for Germany's own needs. There was little to spare for the rebuilding of Europe. Millions of people were cold, and thousands died during the first few winters following the war, owing to the shortage of coal.

The output of coal in Germany and in Britain rose only slowly. One reason for this is the fact that mining is hard work and the miner must be well fed. After the war, most of the population of Europe was underfed, and millions of people lived in a state of semi-starvation. The Ruhr miner could not have worked very hard, even if he had wanted to do so. And he did not want to do so. There was little that he could buy with the wages he received; even food



(*By courtesy of the National Coal Board*)

Miners at work in a gallery of a British coal-mine

was scarce, and the shops were empty of consumer goods, all the goods that make life worth living. He received more food than other people but it was insufficient for a labourer. He had not enough strength for hard work. As soon as more food was shipped from America, the output of Ruhr coal increased.

The industrial prosperity of Britain was built on coal. She has always been rich in coal and iron, and as they are found near each other it costs little to bring one to the other. This was a great advantage when Britain began her industrial development. She soon became the workshop of the world. She produced more coal than she could use and had a good surplus for export. This surplus brought in money from overseas and increased the national wealth. Some of the best coal in the world, anthracite, that burns hotly with little smoke, is mined in Wales. It finds a ready market all over the world.

But British mines are not what they were. They are old. When a mine is new, the coal is near the surface and its extraction is fairly easy and cheap. The deeper the mine, the higher the cost of mining. Coal is found in layers called seams. If the seam of coal runs a mile below the surface of the ground, then the mine must be a mile deep. The passages underground, usually called galleries, may run for miles. In one mine in the north of England, where a recent disastrous explosion caused the loss of more than a hundred lives, the galleries run out for six miles under the *sea*. Thus the miner often has to travel long distances underground before reaching the coal face, which is the name given to the place where the coal is cut. A little railway carries him to the coal face, but even so mining in these circumstances is difficult and expensive. In many mines much of the work of cutting the coal is done by machinery, but in Britain local difficulties often prevent the

full use of cutting machinery. For this reason the output of the American miner is greater than that of the British one. For the first time in her history, Britain, whose wealth was largely founded on coal, had to import some herself in 1947, and again in 1950.

It is a very serious matter when an industrial country runs short of coal. In the first place, nearly all houses in Northern Europe are heated with coal. An ordinary workman's house needs about a ton a year to keep the family warm and to cook the food. It is usually bought in small quantities which last a week or two. When the coalman reports that he has no further supplies, the unhappy family gathers round a half-dead fire in the evenings, and shivers: for in cold countries the fireplace is the centre of the home, the place to which everyone returns. A home without a fire is no home at all in cold weather.

A shortage of coal leads to a shortage of electricity. Most modern factories depend largely on electricity, and when the current fails the wheels stop turning. Work may be possible only four or five hours a day; output and wages fall; prices begin to rise. The workers go back to cold homes, where also the current is cut off during certain hours. Railway and other services are reduced to save fuel. It is a universal calamity.

Throughout the world to-day, there is an enormous demand for coal. In Europe it is needed for rebuilding the ruined cities; for not even bricks can be made without it Industries must be restarted and expanded, and this cannot be done without an ample supply of coal. There is still a shortage of consumer goods throughout the world; prices are high and quality is low. Goods will not become cheap again until the shops are full, and only when supply meets demand will the cost of living begin to fall.

In Britain, there are other things besides the age of the

coal pits to account for the fall in output. Coal mining is a dirty and dangerous occupation, and one that has not paid good wages in the past. For many years few young men have been attracted to the mines. They have preferred to look for other work. Their fathers and mothers have urged them not to go down the mines, but to look for cleaner, better paid, and less dangerous occupations. Many of them have been successful in finding such jobs. As the number of newcomers to the mines decreased, the average age of the miners began to rise. A miner whose age is twenty-five can produce far more than one ten years older, for mining is hard work and needs young, vigorous men. In Britain, not only are the mines old, but so are the miners. The government is now taking steps to make mining more attractive. Many foreigners are finding in mining a chance to make a better living than they ever made in their own countries.

To try to restore mining to its old place in Britain's economy, new laws have been passed. All the private owners of mines have been bought out, and the mines are now national property: they have been nationalized. The miner no longer works for a private owner: he works for the country. The hours of labour have been decreased and a five-day working week has been introduced. Those who absent themselves from work on frequent occasions without just cause are being dismissed. Wages have been raised and up-to-date machinery is being brought into the pits. Young miners are given periods of free training, to fit them for their work.

Many people, especially those who were the owners, disapprove of the nationalization of the coal mines. But no political party had any sensible plan to improve the conditions of the mining industry other than nationalization, and everyone realized that Britain's economic recovery

would be impossible without a reorganization of some kind or other.

* * * * * * *

One may wonder why anyone in his right senses becomes a coal miner. Yet it is the natural occupation of most boys born near the coalfields, just as farm work is the natural occupation of those born in an agricultural district. Ordi nary people have little choice of occupation. When they leave school, they look for work that will enable them to live at home. The natural fate of a miner's son is to be a miner. We cannot choose our own parents; if we could, most of us would probably prefer them to be millionaires or ministers. Fate or luck plays a great part in our lives.

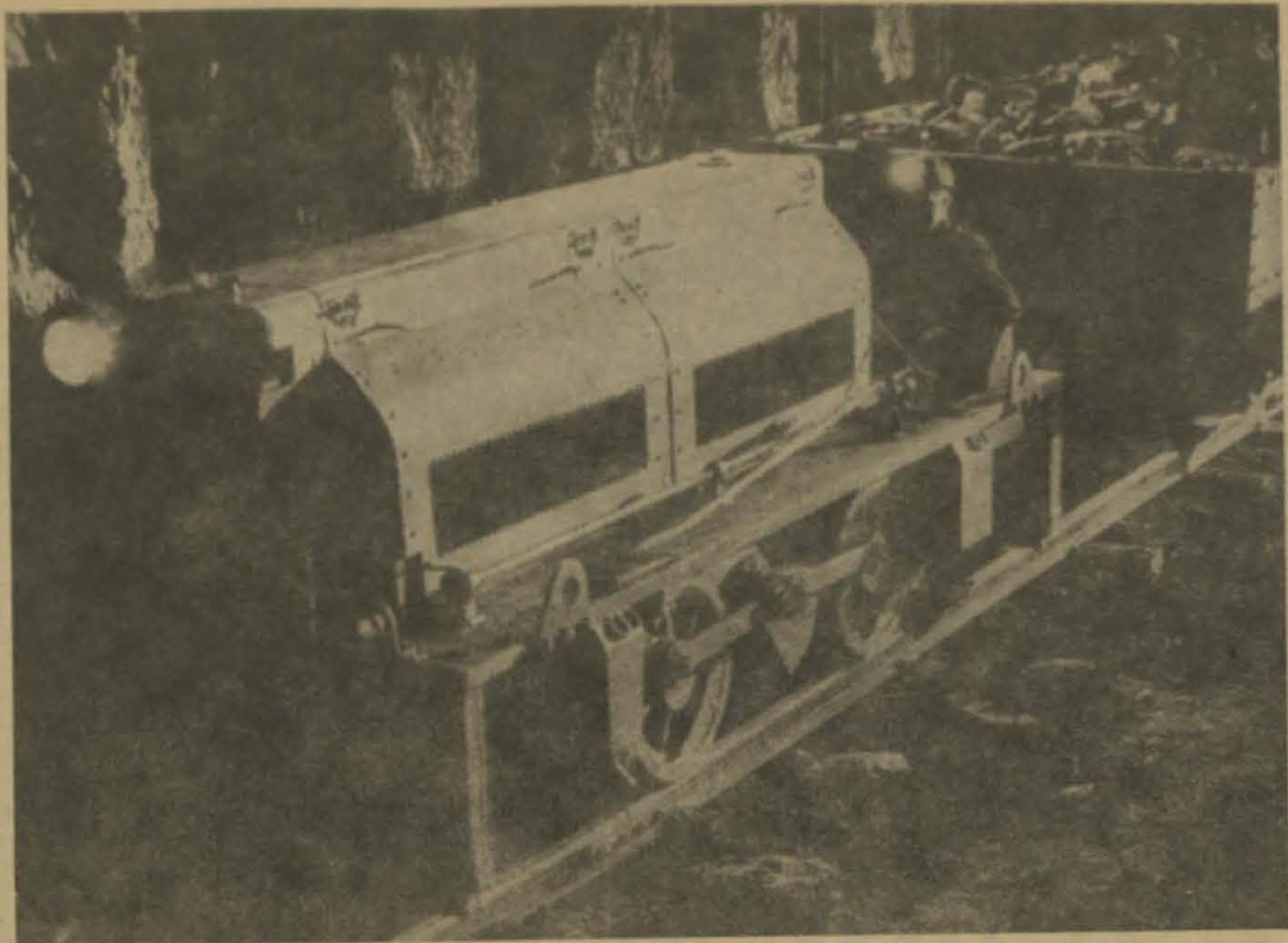
We should, however, remember that the miner does not live a life of perpetual dirt, work and danger. When he comes to the surface at the end of a day's work, he is certainly tired and dirty. The whites of his eyes shine strangely from a face blackened with coal dust. But after a bath, a change of clothing, a meal and a rest, he is a different man, and ready for a visit to his club, the football field or the cinema. Miners are fond of all kinds of sport. If they do not play themselves, they eagerly follow the fortunes of those who do. They are fond of betting, too, and every horse-race that is run takes money out of some pockets and puts it into others. In good times they live cheerful, ordinary lives. They are accustomed to the ever-present danger in the mines, and accept it as a natural part of their existence.

A modern coal mine is a wonderful example of man's skill and courage. To go down a mine is rather alarming the first time. You enter a lift called a cage. Suddenly the bottom seems to fall away under your feet and you feel your heart rising into your mouth. You find yourself

falling, falling, farther than you have ever fallen before. When the cage slows down and stops, you have come to the first level, but you do not get out yet. You are going down much farther, a quarter of a mile farther down. Again the cage stops and you walk out. It is better not to think of the amount of earth and rock that is now above your head, or of what would happen to you if it fell in. You find yourself in an underground town with offices and streets, all lighted with electricity. To reach the coal face, you must go for a long ride in a little waggon, one of the waggons that carry the miners about the mine. The waggon may be drawn by a diesel locomotive, but in some pits ponies are still used, little horses whose work is to pull the loaded waggons from the coal face to the bottom of the shaft.

The mines are much safer places than they used to be. The chief danger comes from gas. There are pockets of explosive gas in some of the coal seams, and when this escapes it is liable to explode. A spark made by a miner's boot kicking against a piece of iron may be sufficient to explode the gas. In the old days, when all the miners had to carry lamps, the invention of a special safety-lamp reduced the number of accidents. Nowadays electricity is used to light the mines and safety-lamps are not needed so much.

Whether work is going on or not, the safety staff is always on duty. This is a body of men whose work is to preserve the safety of the mine and of all who enter it. Water and bad air are two great enemies. Water pumps must be kept going all the time, because if they stopped for any considerable period, many mines would be flooded. Fresh air is always being pumped into a mine, and bad air pumped out; proper ventilation is absolutely essential. It is interesting to note that many mice are used in mines to



(By courtesy of the National Coal Board)

A Diesel engine used for pulling waggons in a coal-mine

detect the presence of gas or poisonous air. As this is usually heavier than ordinary air, a mouse in a cage on the ground feels its effects before a man can feel them. A little bad gas will kill a mouse in a cage; its death indicates the presence of gas, and precautions are immediately taken.

What is coal? It is the remains of huge forests that long ago lived, died and fell, were compressed and heated, heated and compressed, during immense periods of time. The power that is in the coal and that turns the wheels of progress came from the sun in past ages. The heat given out is the sun's heat, heat that was radiated from the sun millions of years ago and stored underground, until man appeared on the earth and, in the course of time, started to dig it out.

CHAPTER II

The Steam-engine

WHEN was the steam-engine invented and who invented it? Many people would answer that James Watt did so in the eighteenth century. There is a story that when he was a boy, James was sitting by the fire one day watching the kettle boil. He noticed that the steam from the boiling water moved the lid of the kettle, and this set him thinking how powerful the steam was. While he was sitting there deep in thought and gazing at the kettle, his aunt came in and blamed him for wasting his time when he ought to have been studying his books. She was wrong to be angry with him, however, for in later years James Watt became one of the most famous makers of steam-engines in the world.

This is a pleasant story; but it is a fact that the power of steam was known more than 1,800 years before Watt was born. In 130 B.C. a small machine driven by steam was made by Hero, a man who was greatly interested in all kinds of mechanics, and who lived in Alexandria. He made a famous toy, a kind of ball which was turned round by steam. It can hardly be called a steam-engine, but it shows that men have been aware of the power of steam for at least two thousand years.

No real progress, however, seems to have been made in the development of the steam-engine until the seventeenth century, when men began at last to realize how useful such a machine could be. In 1698 a man named Savery con-

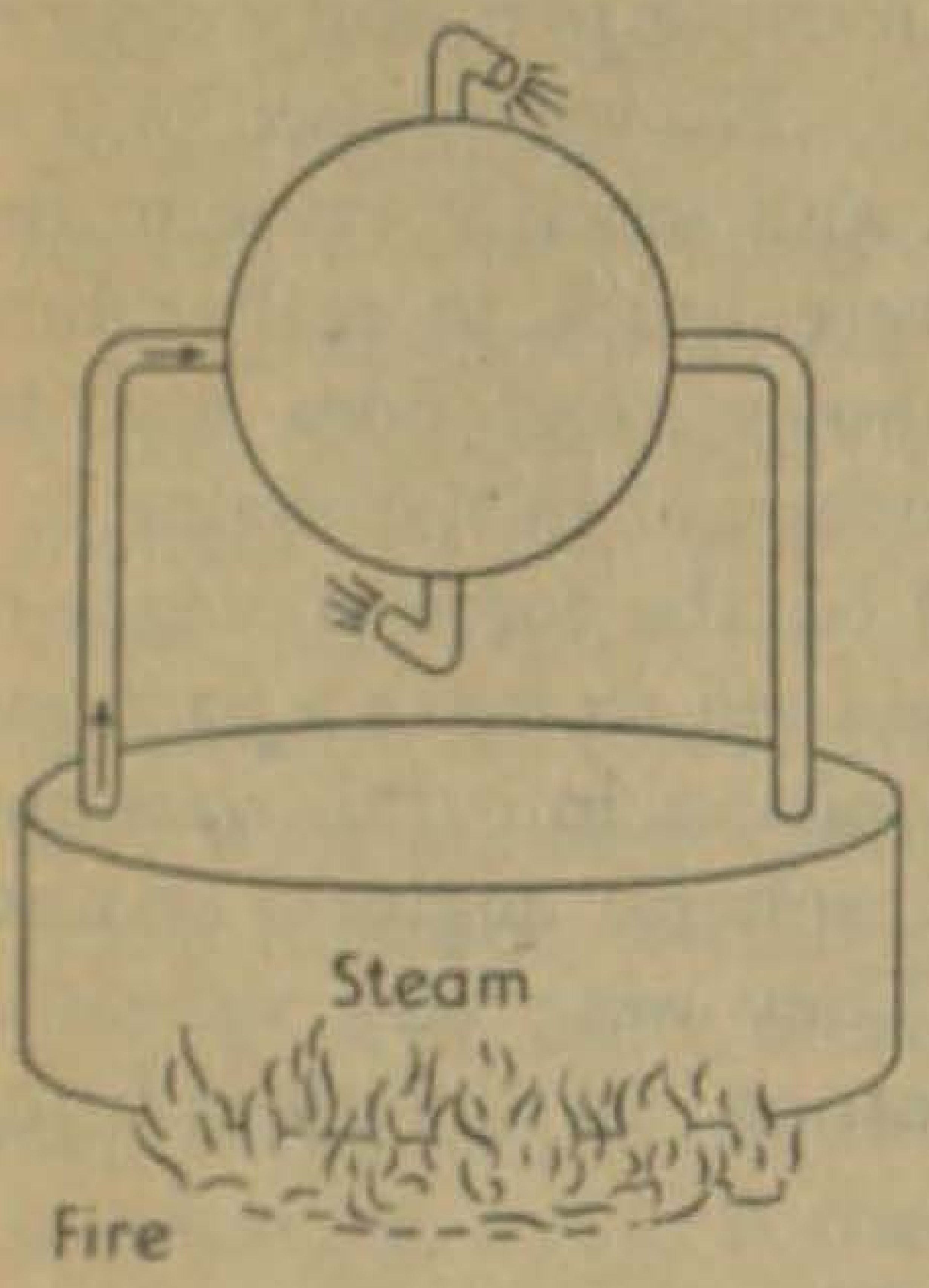
structed an engine for the purpose of raising water out of mines. It worked by steam, but it did not use pistons and cylinders. Steam was led into a vessel and was then condensed, or turned back into water, by cold water on the outside of the vessel. A little water can be made into a great amount of steam; and when the steam is turned back into water, it takes up much less space. The result of condensing the steam in Savery's engine was to form a vacuum inside the vessel, and this vacuum was used to suck up water out of the mines.

* * * * * * *

Early in the eighteenth century, an English engineer called Newcomen made what has been described as the first steam-engine. Newcomen himself and the people of that time called it a fire-engine. It also was used to pump water out of mines, but it did not work in the same way as Savery's engine: it used a piston moving in a cylinder. Pistons and cylinders had been used before this in water pumps, and the idea of applying the principle to the steam-engine was not new. Newcomen, however, constructed an engine which was much better than any that had yet appeared. He used the same idea as Savery in condensing the steam, but he developed a better way of doing it. Steam was let into the cylinder through one valve, and then another valve was opened and admitted cold water. This produced a vacuum inside the cylinder and the piston was sucked inwards. This piston was made to work long rods which reached down the mine and were part of the pump.

It will be seen that some method had to be used in these engines to open and close the valves. At first this was done by hand. Boys were employed to do the work because they did not need to be paid much. One of these boys was Humphrey Potter. Opening and closing valves is dull work,

FIGURE 1 (Hero)



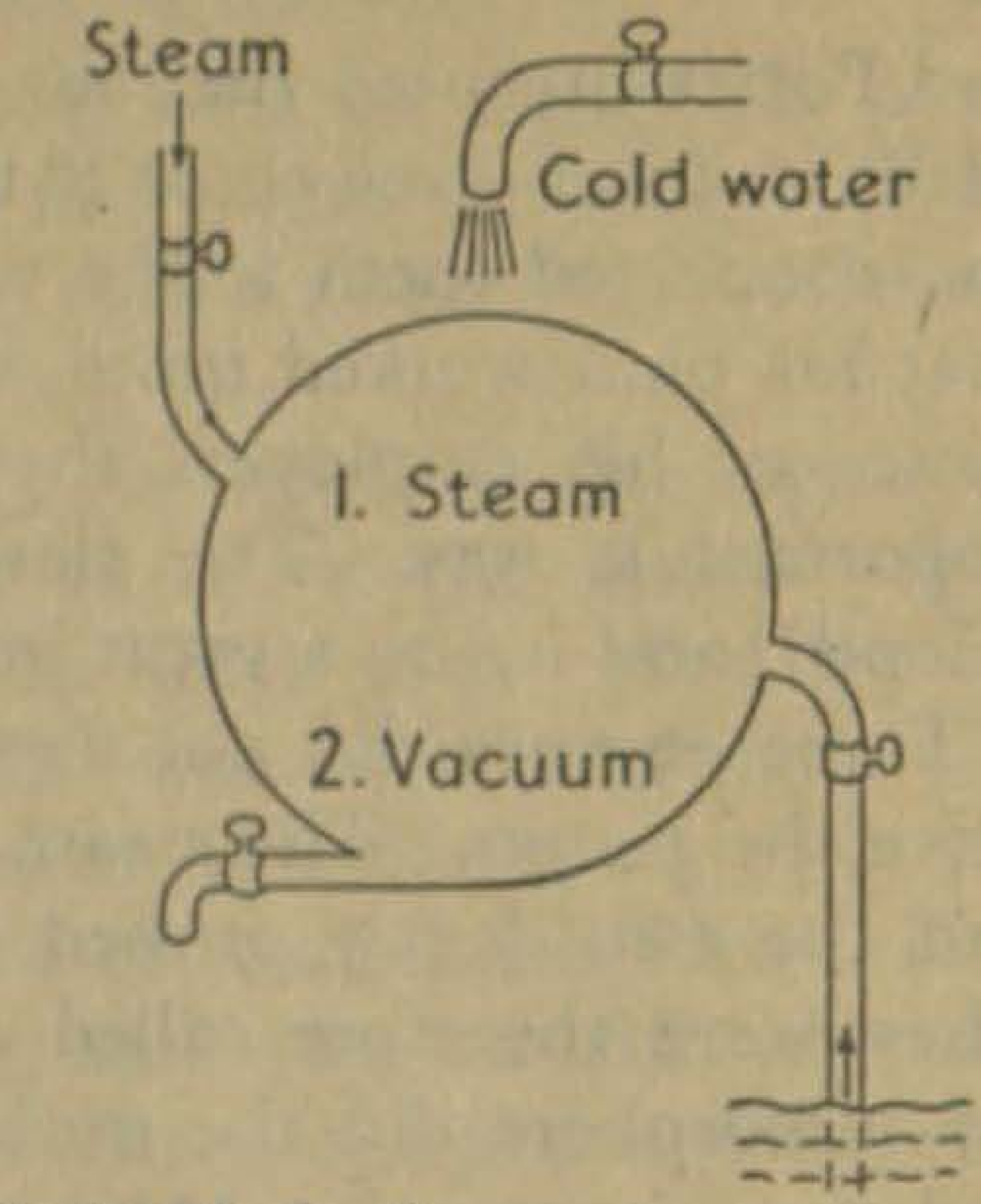


FIGURE 2 (Savery)

FIGURE 3 (Newcomen)

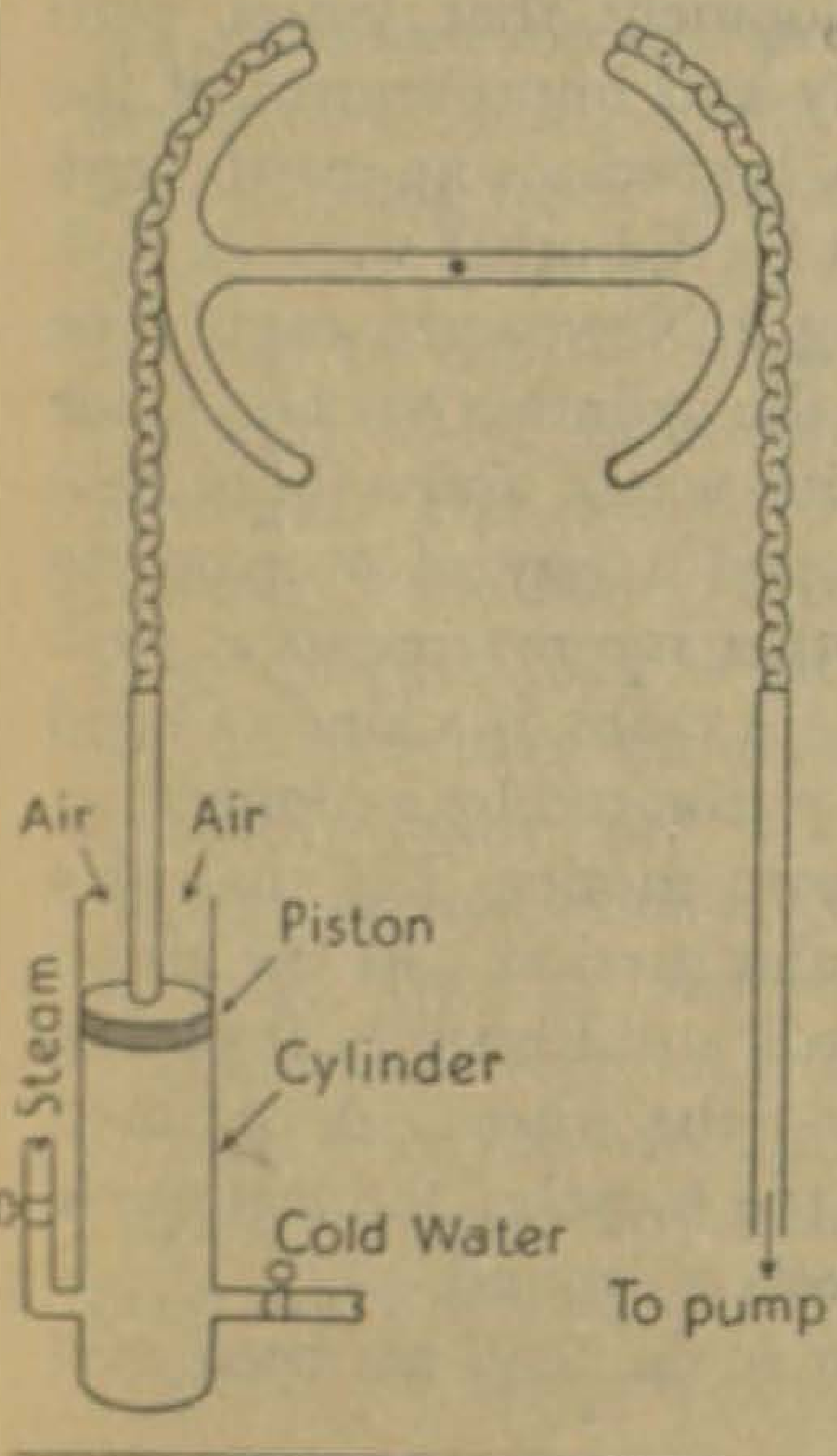
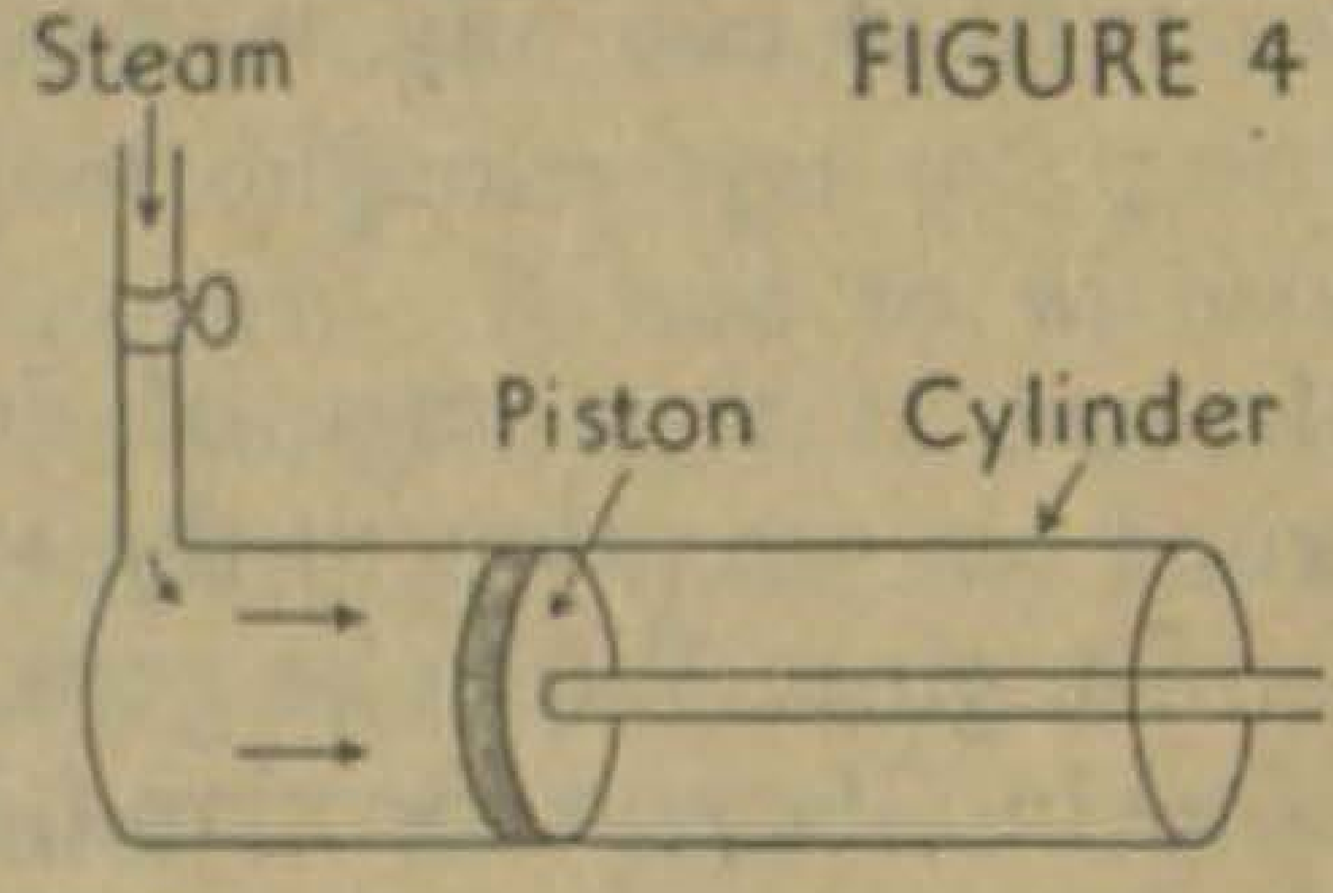
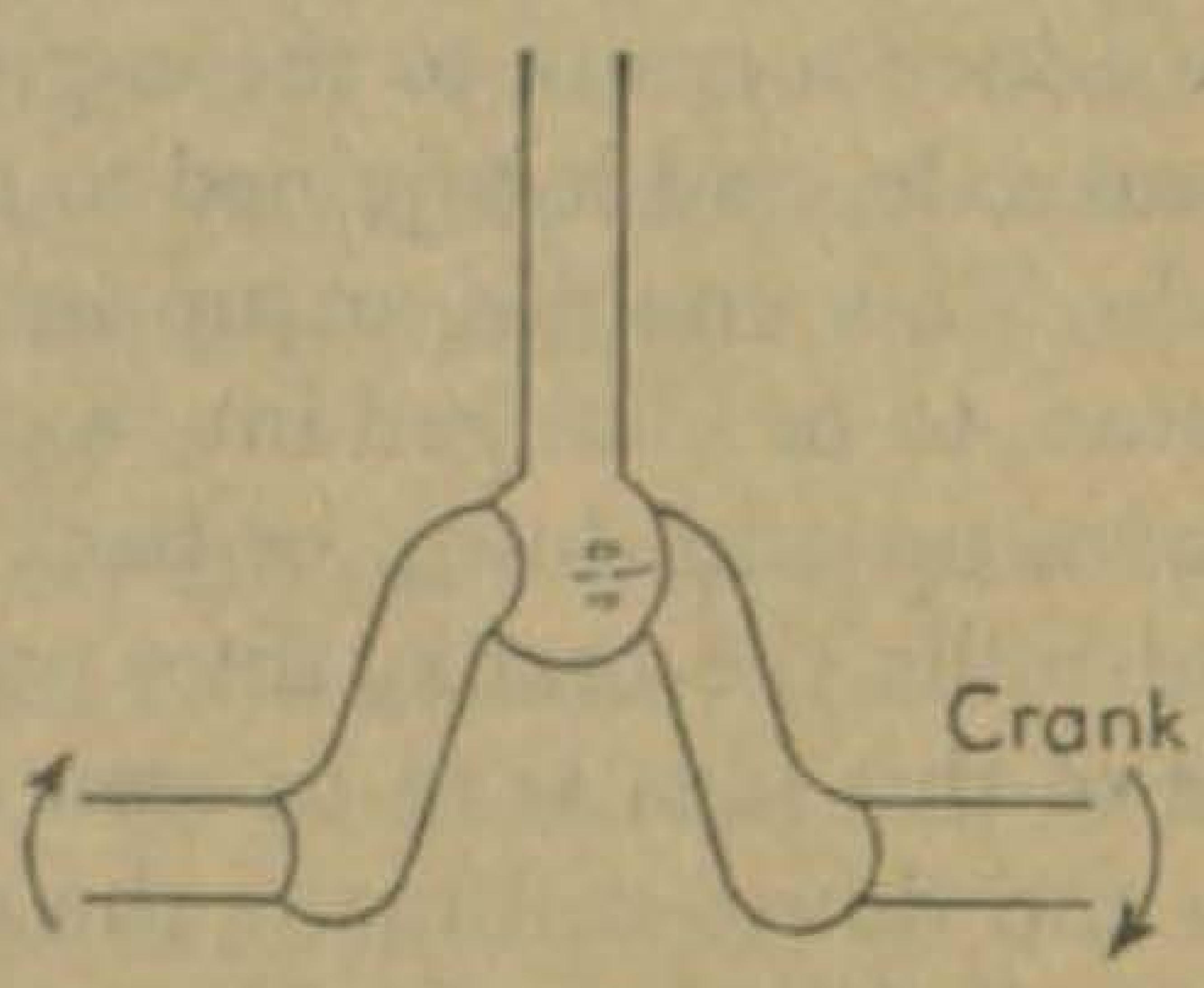


FIGURE 4



(Trevithick & Watt)

FIGURE 5



and Potter invented the idea of making the engine do this itself; he fixed some cords to the moving part of the engine, and connected them to the valves. He was pleased to find that his plan worked quite well, and when it came to the notice of his employers they were quick to realize how important it was. The clever boy's rough idea was developed, and led to a great improvement in the engine.

These engines did not depend on the force of steam to drive the piston. The steam was used to make a vacuum, and the outside air pressed the piston into this vacuum. They were therefore called atmospheric engines, because the atmosphere did the work. They were very successful and were in use for half a century, all the time being improved in one way or another.

* * * * * * *

It was at this stage of development that James Watt turned his attention to the study and improvement of the steam-engine. When he grew up, he became an instrument-maker in Glasgow, Scotland, but he did other work as well. One day, when he was mending a Newcomen engine, he noticed how wasteful it was; for the cylinder was first made hot with steam and then cold with water, and a lot of heat was lost. Watt not only developed a way of overcoming this difficulty, but made many other improvements as well. He added a crank to the engine. A crank is a kind of bend in an axle, and it is joined to the piston-rod by a connecting-rod. This enables an up-and-down motion, like that of a piston, to be changed into a circular motion. As the piston moves up and down, or backwards and forwards, it pushes and pulls the crank, thus turning the wheel. A common use of this idea is to be seen on the bicycle: the feet move up and down and make the wheels go round.

Until this time the Newcomen engine had not been used

for turning wheels. It had been used for things like pumping, where an up-and-down movement is needed. When the steam-engine was made to turn a wheel, it could be used for many other purposes.

Another improvement that was made in the engine was to use high-pressure steam to drive the piston. Watt thought out this plan and so did a man called Richard Trevithick, who lived in the south-west of England, in Cornwall. A violent quarrel arose between the two men, and Watt accused Trevithick of stealing his idea. Trevithick, however, did not care, and went on with his plans. This idea of using steam to drive the piston, instead of depending on the pressure of the atmosphere, was of major importance, and it is the principle upon which all modern steam-engines work. The chief difficulty was to construct a boiler which was strong enough. It had to withstand the enormous internal pressure; for if it burst, the escaping steam and boiling water would kill or injure anyone who was standing near. Even to-day there is always the possibility that a boiler may burst if the pressure inside is allowed to rise too high. That is why a safety-valve is provided, to let the steam escape when it reaches a certain pressure. The safety-valve of a locomotive is usually on the top of the boiler, at the back; strong springs keep the valve closed as long as the internal pressure is not too great, but when it rises too much the valve opens and a fierce jet of steam shoots out. You have probably noticed this at a railway station, when a locomotive is standing at a platform ready to begin its long journey.

It was not very long before the difficulty of making a strong boiler was overcome, and the modern type of steam-engine made its appearance. Its success was immediate. Soon every manufacturer was demanding one of the new engines, not for pumping purposes but for use in his fac-

tory. From the north to the south of England the wheels of industry began to turn faster and faster. The cheap power enabled the country to supply the world with goods. Factories sprang up in great numbers, and people flocked from the country to the towns. The industrial revolution, which had already begun, gathered speed. The new steam-engine was changing the lives of men.

CHAPTER III

The Locomotive and the Railway

WHEN the stationary steam-engine was at work in all parts of England, several men began to wonder whether they could make an engine that would move itself along a road. At the beginning of the eighteenth century the transport of coal from the mines to other places such as ports was carried on by carts on the roads, and by boats on the canals. A travelling steam-engine could perhaps be used for pulling coal waggons. The chief difficulty was the enormous weight of the engine, coupled with the terrible condition of many of the roads at that time. How could a heavy engine be made to move along muddy roads on which even carts often stuck? The problem was certainly not an easy one to solve.

In spite of the obvious difficulties, Richard Trevithick, the maker of stationary engines, decided to try to construct one that would move itself. He did make a travelling engine, but no one seemed to want it, and the roads were so bad that it was not a great success. Another man, a Frenchman called Cugnot, also made a kind of locomotive, but it fell over after it had been tried once or twice and, to prevent any further accidents, it was put away and used no more.

Trevithick, however, still kept in his mind the idea of making a successful locomotive. He had a friend and partner called Homfray, the owner of an ironworks engaged in making stationary steam-engines. The nearest

amid scenes of great excitement, Trevithick drove it along Homfray's plate road, pulling ten tons of iron in the waggons behind. Cows and sheep in the fields looked up, first in astonishment and then in fear, as the awful monster, making horrible noises, appeared on the road in clouds of steam and smoke. The animals fled in terror across the country, and were soon joined by many of the horses of the onlookers who had come to watch the experiment. As the first train in the world moved along at five miles an hour, many excited people climbed on the waggons and rode to the end of the journey cheering and shouting at the tops of their voices. When Trevithick got down from the engine at the conclusion of his remarkable journey, he found himself surrounded by a crowd of enthusiastic and noisy people who poured their congratulations into his ears. It was a great triumph.

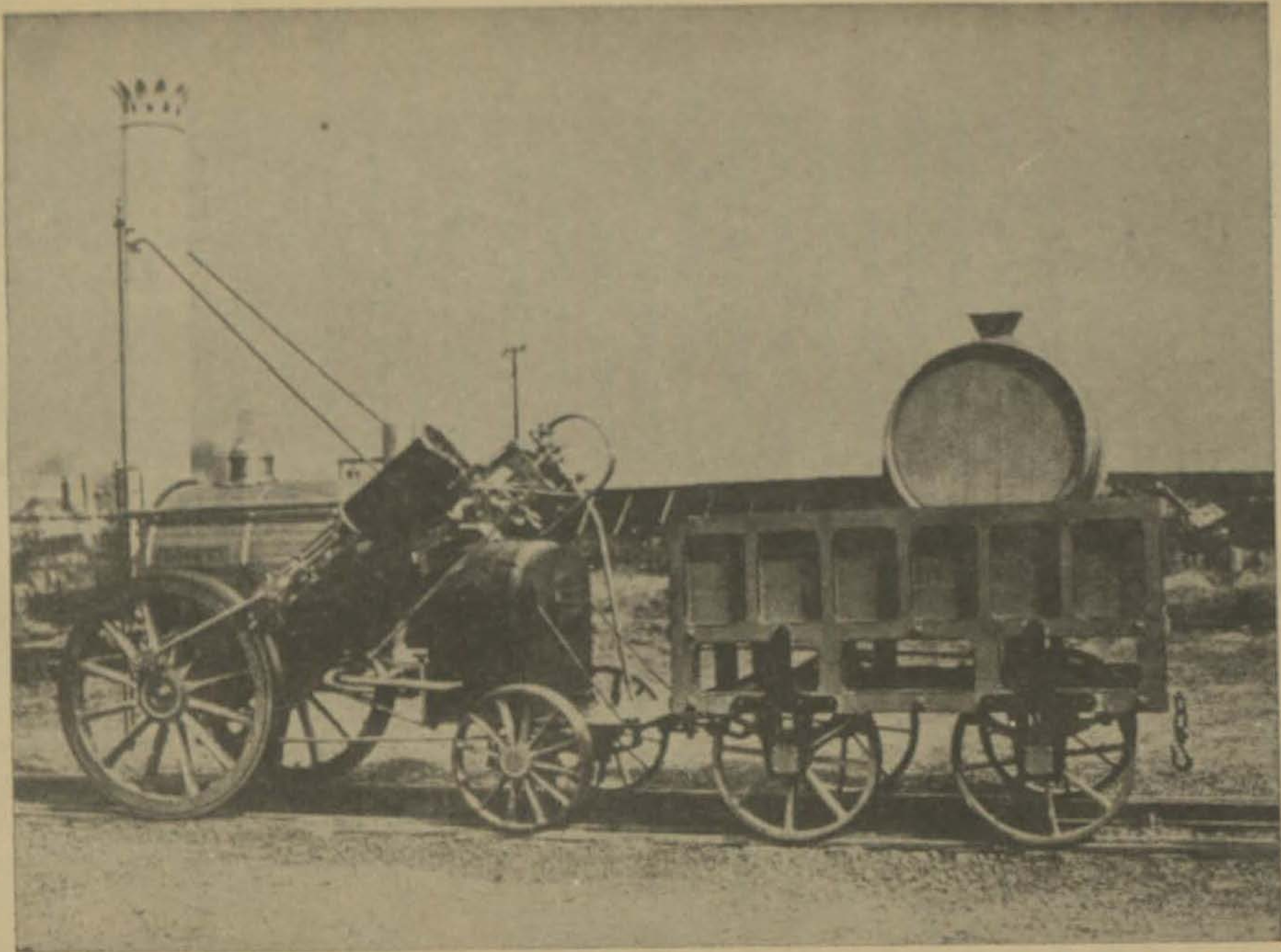
Yet the triumph was not so complete as it appeared. The heavy engine broke some of the plates on the road, and during the journey the wheels sometimes slipped and failed to move the train. It took about a week to mend the road after this single journey. If every train was going to break up the road and put it out of action for a week, it was clear that this method of transport would never be a success. Wise men shook their heads and said that the time had not yet come to make travelling engines. Trevithick himself agreed with them and turned to other inventions. Nevertheless, let us remember with honour the man who made and drove the first train in the world carrying passengers and goods.

* * * * * * *

It was not until strong rails had been successfully made that the railway was born. Even then, a lot of trouble was caused because the driving wheels kept slipping. There

was only one pair of driving wheels on Trevithick's locomotive and on the others built at that time, and these wheels sometimes turned without moving the train. A man called Brunton tried to overcome the difficulty by making a kind of carriage driven by levers. It was worked by a steam-engine, and pushed itself along with bars of iron, rather like a horse's legs. This queer machine, however, does not seem to have been very successful. Another way of preventing the slipping of wheels was invented by an engineer called Blenkinsop in 1811. He fixed a toothed wheel to the engine. This toothed wheel fitted into a special kind of rail on the ground called a rack-rail, and prevented the other wheels from turning uselessly. It was a much better idea than Brunton's levers, and is used nowadays on mountain railways where the train has to climb steep hills.

At about this time a poor boy named George Stephenson was growing up and working at a coal mine in the north of England. His father was too poor to send his son to school, and George received no education until he was eighteen years old. At the mine he saw and studied the stationary engines which were in use there. After he had learnt how they worked, he began to wonder whether he could make a better locomotive than the rather unsuccessful machines which had so far appeared. George Stephenson built many locomotives in his life, but the most famous of all is undoubtedly the "Rocket" which was completed in 1829. This engine could move faster and draw heavier loads than any of the earlier machines. Among the improvements later introduced by Stephenson was the use of four driving wheels instead of two; this avoided much of the slipping which had been so troublesome before. His engines were, in fact, so much better than the earlier types that he is often considered the inventor of the locomotive. Though



(Photo: Locomotive Publishing Co. Ltd.)

Stephenson's "Rocket"

this may not be strictly true, there is no doubt that his name is and will remain one of the most famous in the history of railway development.

George Stephenson not only built many successful locomotives, but also worked at the planning and laying of railways. He had a son, Robert, who also became a famous railway engineer and followed in his father's footsteps. Robert received a good education, for his father remembered his own early days and was determined to give his son a better start on the difficult road of life. When Robert grew up he was honest, untiring at work, and confident in the face of difficulties, like his father before him. At one period he worked for the London and Birmingham Railway as engineer. While the line of this new railway was under construction, it is said that Robert walked the distance between the two cities, a matter of about a hundred miles, twenty times or more. He travelled abroad, too, and helped to build railways on the continent of Europe, and in Canada, Egypt and India. These two famous men, father and son, did more than anyone else to help the early development of the railways of the world.

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A lot of people objected strongly to the railways which were beginning to spread over England's countryside. Many old ladies, accustomed to ride peacefully in their carriages along the country roads, expressed their fixed determination never in any circumstances to travel by railway. Other people prophesied that the boilers would burst and kill everyone in the train, and probably a lot of other people too. Those who lived in the houses near which the lines were laid complained of the noise and smoke. The people of those days were very sorry for the cows and other animals in the fields. The cows would breathe smoke and

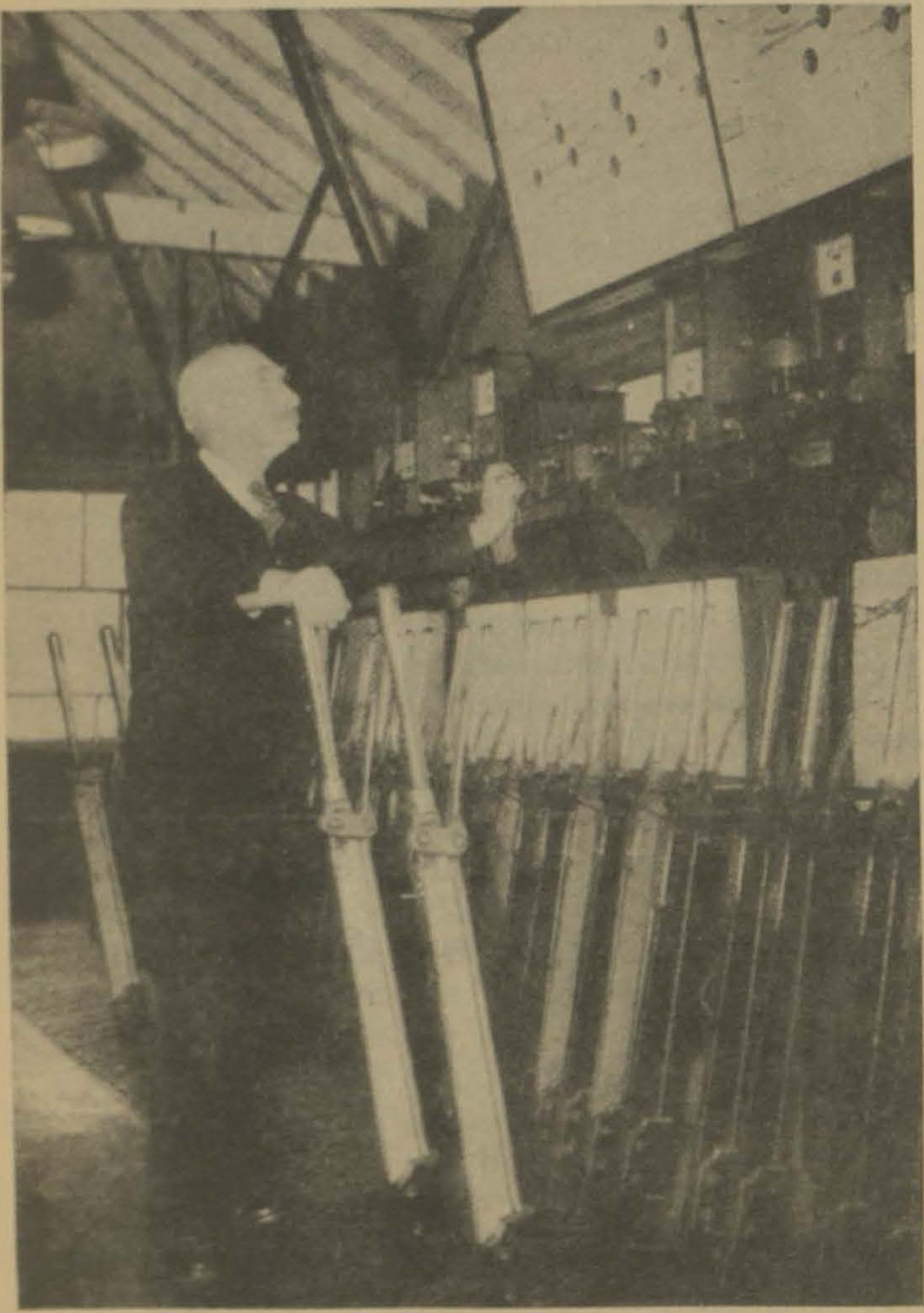
steam, and would fall ill! The dreadful noise would terrify the poor cows! "Would it not be very awkward if a cow got on the line in front of a train?" said one man to George Stephenson. "Very awkward, indeed," said George, "for the cow!"

Those who prophesied accidents were quite right. The first train to run on an early railway which was opened in 1830 killed a man. Other misfortunes occurred. As the number of trains increased, there was always the danger that one might run into another. To try to prevent this, a system of signalling was introduced. Signals were put up along the line, and a man used to stand at each and put it at "Danger" after a train had passed. About ten minutes later the signal was put at "Line clear" and the next train was allowed to pass. Although this method was better than none at all, it was very imperfect. If a train, after passing a signal, stopped for any reason out of sight of the signalman, he was quite unaware of this and set his signal at "Line clear" when the time came. In that case there was nothing to prevent an accident. It was not until a group of signals was worked from one signal-box, and the boxes were connected by electric telegraph, that railway travel became reasonably safe. Since that time many improvements have been made in signalling. Each line is now divided into sections, and two trains are never allowed in the same section at the same time. Electric indicators worked by the trains themselves are placed in each signal-box to show the signalman where the trains are. It is impossible on most lines now to set a signal at "Line clear" if the points (the junctions between two lines) are not in the correct positions. Many of the latest signals are worked by electricity and compressed air, and the signalman has only a small lever to move. Many, too, have red, yellow and green lights instead of the old moving arm; these are

similar to the modern traffic lights seen in the streets of a city. Some of them are automatic and show a red light immediately after a train has passed, without any action by the signalman. In some signal-boxes the movement of one small lever will set all the signals and points for one track correctly. It is not easy at the present time for a signalman to make a serious mistake.

Another addition to the safety of railway travel is provided by the air brake. A train is very heavy indeed and travels at great speeds. A single brake on the wheels of the locomotive is of little use to stop a modern express moving at sixty miles an hour. You have probably noticed a pipe leading from the locomotive to the first coach, and from every coach to the one behind. This is the air brake. As long as the air pressure in the pipe is the same as that of the outside air, brakes press on every wheel in the train. When the driver moves a lever in his engine, the air pressure in the pipe is changed and pistons under each coach take the brakes off, thus allowing the train to move. When he presses his lever the opposite way, all the brakes throughout the train are applied to the wheels and the train soon stops. If there is an accident and the train breaks into two parts, the pipe is also broken, air rushes into it and all the brakes are automatically put on. This air brake has prevented many railway disasters.

Many other clever ideas have gone to make our railway journeys safe. When next we buy a ticket to take us to our work or to the seaside, let us give a thought to those men in the past who overcame many difficulties and disappointments and made our journey possible.



(*Photo: Fox Photos Ltd.*)

A railway signal-box

CHAPTER IV

Oil

OILS of many kinds play a large part in the life of each of us. If your skin is sunburnt, rub some oil into it. Is your hair too dry? Put oil on it. When you eat your salad, remember to take some oil with it. Oil your bicycle to make it go well. Keep a sufficient quantity of oil in your motor-car engine or you will ruin it. Yes, oil is important in many ways; but the kinds of oil which we use for different things may have different origins. No one would like a dinner cooked in engine-oil, and no one should put vegetable oil into a motor-car.

There are three main groups of oils, animal, vegetable and mineral. Great quantities of animal oil come from whales, those enormous creatures of the sea which are the largest remaining animals in the world. To protect the whale from the cold of the Arctic seas, nature has provided it with a thick covering of fat called blubber. When the whale is killed, the blubber is stripped off and boiled down, either on board ship or on shore. It produces a great quantity of oil which can be made into food for human consumption. A few other creatures yield oil, but none so much as the whale. The livers of the cod and the halibut, two kinds of fish, yield nourishing oil. Both cod liver oil and halibut liver oil are given to sick children and other invalids who need certain vitamins. These oils may be bought at any chemist's.

Vegetable oil has been known from antiquity. No house-

hold can get on without it, for it is used in cooking. Perfumes may be made from the oils of certain flowers. Soaps are made from vegetable and animal oils.

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To the ordinary man, one kind of oil may be as important as another. But when the politician or the engineer refers to oil, he almost always means mineral oil, the oil that drives tanks, aeroplanes and warships, motor-cars and diesel locomotives, the oil that is used to lubricate all kinds of machinery. This is the oil that has changed the life of the common man. When it is refined into petrol it is used to drive the internal combustion engine. To it we owe the existence of the motor-car, which has replaced the private carriage drawn by the horse. To it we owe the possibility of flying. It has changed the methods of warfare on land and sea. This kind of oil comes out of the earth. Because it burns well, it is used as fuel, and in some ways it is superior to coal in this respect. Many big ships now burn oil instead of coal. Because it burns brightly, it is used for illumination; countless homes are still illuminated with oil-burning lamps. Because it is very slippery, it is used for lubrication. Two metal surfaces rubbing together cause friction and heat; but if they are separated by a thin film of oil, the friction and heat are reduced. No machine would work for long if it were not properly lubricated. The oil used for this purpose must be of the correct thickness; if it is too thin it will not give sufficient lubrication, and if it is too thick it will not reach all the parts that must be lubricated.

The existence of oil wells has been known for a long time. Some of the Indians of North America used to collect and sell the oil from the wells of Pennsylvania. No one, however, seems to have realized the importance of this oil

until it was found that paraffin-oil could be made from it; this led to the development of the wells and to the making of enormous profits. When the internal combustion engine was invented, oil became of world-wide importance.

It is sometimes found in the most unlikely places. In the West Indies it is actually found under the sea bed. Huge structures stand in the water and pump up the oil from below. The burning deserts of Arabia cover rich deposits of oil which will provide the country with most of its revenue. In Bahrein American drillers succeeded in striking oil, and the Bahrein oilfield is now in full production. The revenue of the Sheikh no longer comes from the pearl fisheries but from the oilfields. Being a wise ruler, he is spending much of the money which is received as royalties on improving the welfare of his people. Hospitals and schools are being built and a better life is beginning.

Many people agree that the world will soon have to face an oil shortage. There may be plenty of oil still hidden beneath the surface of the earth; yet the oil men have been everywhere and they believe that very few fields remain to be discovered. If they are right, we may already be in sight of the end of the oil age, an age which has not lasted long. Fifty years ago the horse-drawn carriage was still king of the road; fifty years hence it is possible that the smell of petrol fumes may have been forgotten. In 1944 it was estimated that the total known reserves of oil, in places where it may be obtained at a reasonable cost, amounted roughly to fifty-one thousand million barrels. In 1943 the total world production of oil was over two thousand million barrels. If these figures are correct, it is clear that difficulties will arise in about twenty-five years. Yet some people deny that the world will soon face an oil shortage. The position is serious, but new fields are being developed in Arabia and Russia. There is oil, too, in places which cannot

easily be reached. The area round the North Pole shows signs of having large oil deposits, but it would obviously be difficult to obtain this oil. There is also thought to be oil in Abyssinia, but the difficulty there is that a long pipeline would have to be built to the coast. Then heavy payments would have to be made to the Suez Canal Company as the oil passed through the canal. It is therefore likely that the oil in these two regions will stay where it is for a long time to come.

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What was the origin of the oil which now drives our motor-cars and aircraft? Scientists are confident about the formation of coal, but they do not seem so sure when asked about oil. They think that the oil under the surface of the earth originated in the distant past, and was formed from living things in the sea. Countless billions of minute sea creatures and plants lived and sank to the sea bed. They were covered with huge deposits of mud; and by processes of chemistry, pressure and temperature were changed through long ages into what we know as oil. For these creatures to become oil, it was necessary that they should be imprisoned between layers of rock for an enormous length of time. The statement that oil originated in the sea is confirmed by a glance at a map showing the chief oilfields of the world; very few of them are far distant from the oceans of to-day. In some places gas and oil come up to the surface of the sea from its bed. The rocks in which oil is found are of marine origin too. They are sedimentary rocks, rocks which were laid down by the action of water on the bed of the ocean. Almost always the remains of shells, and other proofs of sea life, are found close to the oil. A very common sedimentary rock is called shale, which is a soft rock and was obviously formed by being

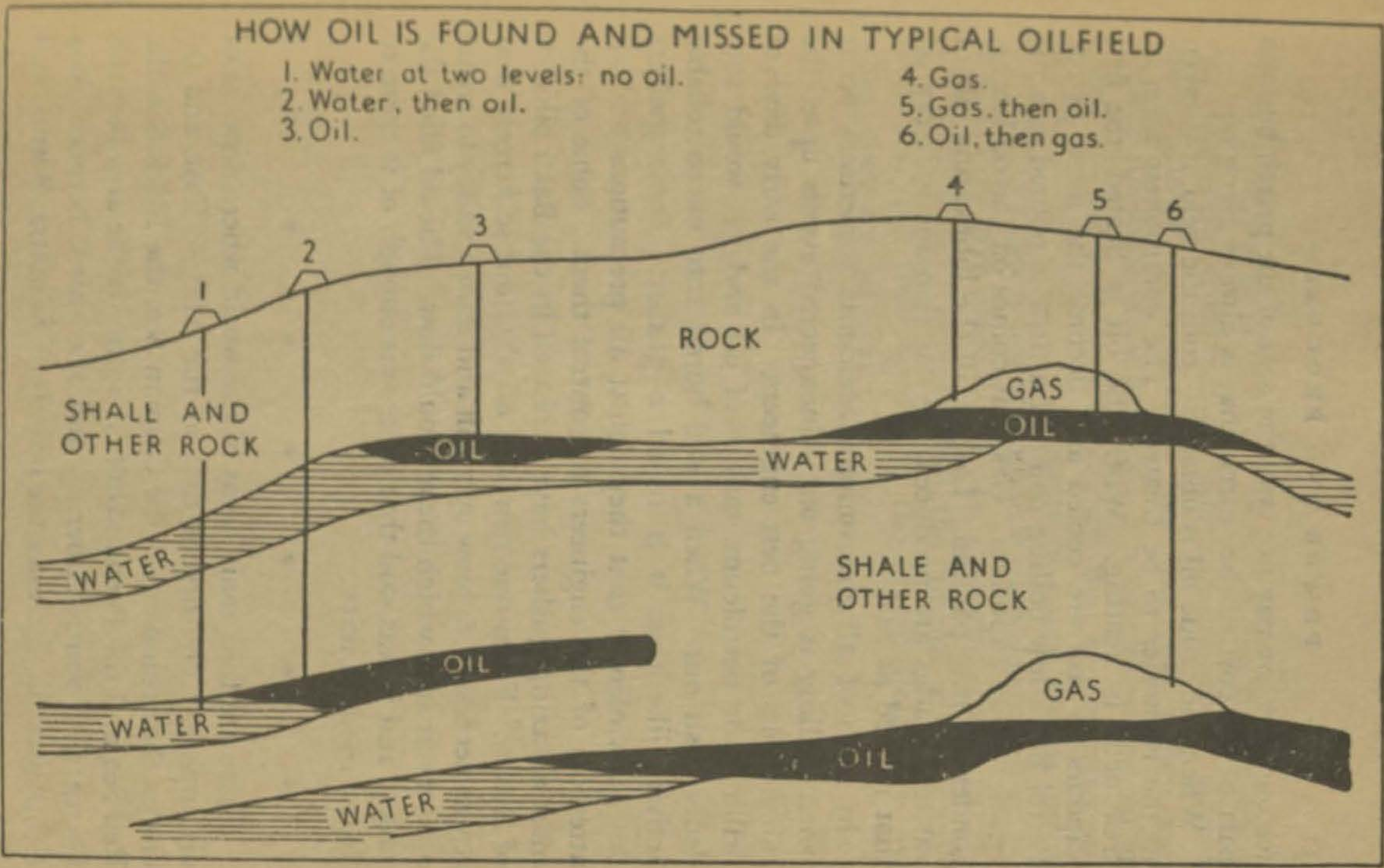
deposited on the sea bed. And where there is shale there is likely to be oil.

Geologists, scientists who study rocks, indicate the likely places to the oil drillers. In some cases oil comes out of the ground without any drilling at all and has been used for hundreds of years. In the island of Trinidad the oil is in the form of asphalt, a substance used for making roads. Sir Walter Raleigh visited the famous pitch lake of Trinidad in 1595; it is said to contain nine thousand million tons of asphalt. There are probably huge quantities of crude oil beneath the surface.

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The king of the oilfield is the driller. He is a very skilled man and receives high wages. Sometimes he sends his drill more than a mile into the earth. The deepest oil well in the world is at Belridge in America; it is more than two miles deep. During the process of drilling, gas and oil at great pressure may suddenly be met, and if this rushes out and catches fire the oil well may never be brought into operation at all. This danger is well known and steps are always taken to prevent it.

There is a lot of luck in drilling for oil. The drill may just miss the oil although it is near; on the other hand it may strike oil at a fairly high level. When the drill goes down, it brings up soil. The samples of soil from various depths are examined for traces of oil. If they are disappointed at one place, the drillers go to another. Great sums of money have been spent, for example in the deserts of Egypt, in "prospecting" for oil. Sometimes little is found. Only rich companies can afford to spend these sums of money; governments are unwilling to spend millions of pounds unless they are sure that the money will come back to them in some way. When we buy a few gallons of petrol


HOW OIL IS FOUND AND MISSED IN TYPICAL OILFIELD
1. Water at two levels: no oil.
2. Water, then oil.
3. Oil.
4. Gas.
5. Gas, then oil.
6. Oil, then gas.
1
2
3
4
5
6
ROCK
SHALL AND
OTHER ROCK
GAS
OIL
OIL
WATER
WATER
SHALE AND
OTHER ROCK
OIL
GAS
WATER
OIL
WATER

B*

for our cars, we pay not only the cost of the petrol, but also part of the cost of the search that is always going on.

When the crude oil is obtained from the field, it is taken to the refineries to be treated. The commonest form of treatment is heating. When the oil is heated, the first vapours to rise are cooled and become the finest petrol. Petrol has a low boiling point; if a little is poured into the hand, it soon vaporizes. Gas that comes off the oil later is condensed into paraffin. Last of all the lubricating oils of various grades are produced. What remains is heavy oil that is used as fuel.

In spite of all precautions, accidents sometimes occur when drilling is going on. Unexpected events upset the calculations of the best engineers. In the early days of drilling for petroleum, masses of oil and gas would suddenly rush out. When a well bursts into uncontrollable activity like this, it is called a gusher. Some gushers flow so violently that they defeat all precautions and all attempts of the engineers to control them. Some of the most amazing gushers have appeared in the Baku oilfields of Russia. From one new well oil shot out so fiercely that it was necessary to blow up a cliff and dam a valley to create a reservoir into which the oil could flow. The oil filled the valley, and it was said that there was enough of it there to float a modern navy.

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There are four main areas of the world where deposits of oil appear. The first is that of the Middle East, and includes the regions near the Caspian Sea, the Black Sea, the Red Sea and the Persian Gulf. Another is the area between North and South America, and the third, between Asia and Australia, includes the islands of Sumatra, Borneo and Java.

The fourth area is the part near the North Pole which has already been mentioned. When all the present oilfields are exhausted, it is possible that this cold region may become the scene of oil activity. Yet the difficulties will be great, and the costs may be so high that no company will undertake the work. If progress in using atomic power to drive machines is fast enough, it is possible that oil-driven engines may give place to the new kind of engine. In that case the demand for oil will fall, the oilfields will gradually disappear, and the deposits at the North Pole may rest where they are for ever.

CHAPTER V

Flying

THE idea of flying has been in the minds of men from very early times. Why were they not content to stay on the ground where they lived? What made them want to imitate the birds? There are always some men in the world trying to do things that have never been done before. There is something in the mind that drives them on to attempt new conquests and new successes. It was only natural that the sight of birds flying through the air should suggest the possibility that man might do the same. It looked easy; but it turned out to be exceedingly difficult. Many brave men have given their lives to make flying what it is to-day.

There is a story of long ago that a man called Daedalus and his son Icarus were imprisoned in the island of Crete in the Mediterranean Sea. They decided to escape by flying away from their prison through the air. They made some wings of feathers and fastened them to their shoulders with wax. Daedalus told his son to follow him, and they set out across the sea to Sicily. Daedalus was wise and was content to fly at a moderate height. But Icarus, being young, was more adventurous and less wise; he became excited with this new way of travelling and flew high up, too near the sun, which melted the wax holding the wings to his shoulders. He fell into the sea, and Daedalus reached Sicily alone.

This old story shows that, even in the ancient days, men

were thinking how wonderful it would be to fly. Yet it is only a story and, like many of the things which we read about in old books, it came from men's imaginations and not from real events.

Many have heard the story of Abbas Ibn Firnass, who was an Arab living in Spain after his countrymen had conquered that country. He decided to fly. Fixing wings to his arms, he jumped off from a high place but, after flying for a short distance, fell to the ground and was hurt. His failure was supposed to be due to the fact that he had omitted to provide himself with a tail.

There are other stories about flying later on in the history of the world. One of them tells how an Italian decided to show King James the Fourth of Scotland that it was quite possible to fly. He flew off from Stirling Castle in Scotland, using wings made from the feathers of birds, and we are not surprised to hear that the attempt was a failure. He fell to the ground and broke his legs. To explain his failure, he said that he had used the wrong kind of feathers, but we do not hear that he tried again.

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In the thirteenth century there lived a remarkable man called Roger Bacon. Among other things, he is said to have invented gunpowder and the air-pump. He suggested that a hot-air balloon would rise in the air. His idea was to construct a hollow sphere or ball and use a fire to make the air inside hot. This plan was very different from the earlier one of using wings made of feathers, and we know that it was successfully put into practice hundreds of years later. But Bacon lived too early in the world's history; the world was not ready for his idea, and it remained only an idea in his lifetime.

Centuries after Bacon had made his sensible suggestion

some very foolish ones were made. One man thought that a swan's eggs filled with mercury and sulphur would rise towards the sun. Another said that vessels filled with the dew of morning would carry a man up into the air. Nonsense of this kind shows that men knew nothing whatever about the conditions that would make flight possible. If they had tried their own ideas, they would soon have discovered how useless they were.

Not until the eighteenth century did flying actually begin. Two brothers whose name was Montgolfier noticed that paper bags rose into the air over a fire. They were Frenchmen, and after them France was to take a leading part in the early development of flying. They succeeded in making a hot-air balloon which rose in the air. After the first experiment they decided that the time had come for the first air passengers to make their journey. These passengers, however, were not people; they were a duck, a sheep and a cock. The sheep unfortunately injured the cock before they set out; but apart from this small accident the animals suffered no harm, and made a successful flight of about eight minutes in the balloon.

Encouraged by this experiment, other men in France tried a balloon filled with hydrogen instead of hot air. Cavendish, an English scientist, had found in 1766 that hydrogen is lighter than air, and it seemed probable that a balloon filled with this gas would rise satisfactorily. It did. It went up to three thousand feet and stayed in the air three-quarters of an hour. It came down near some French farm-workers, who were so angry and terrified when they saw this monster come down from the sky into their fields that they tore it to pieces.

In one of the first ascents by balloon the passengers were a cat and a dog. As the balloon was descending, loud shouts warned a householder that something unusual was

happening. Rushing into his garden to find out what was the matter, he was surprised to see a cat and a dog fall at his feet out of the sky. The animals, finding that they were approaching the earth, had jumped out. He was so amazed that he cried out, "Good heavens! It's raining cats and dogs!" People laughed, for he seemed to give a real meaning to the old saying, "It's raining cats and dogs," which also means that it is raining very heavily.

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The next necessary step was for a *man* to go up in a balloon. In the history of invention and discovery, there often comes a time when some daring act must be done if any further progress is to be made. Men with the necessary courage are always to be found, a fact which may make us proud to belong to the human race, whatever its faults may be. In October 1783, a man called Pilatre de Rozier went up in a Montgolfier fire-balloon. The fire was made of chopped straw and was carried underneath. This balloon was not allowed to fly away, but was fastened to the ground by a long rope. In the following month, accompanied by the Marquis d'Arlandes, de Rozier went up in a free balloon and travelled five miles, rising to five hundred feet on the way. This was the beginning of man's conquest of the air, for others, encouraged by de Rozier's success, made other flights of the same kind, some of them using hydrogen in their balloons instead of hot air.

Lunardi was a famous balloonist in Great Britain. The Prince of Wales was among the enormous crowd of people who went to see him go up in 1784. He took with him a dog, a cat and a pigeon. With the idea of trying to guide the balloon, he took oars up too. He made a successful flight lasting an hour and a half, came down safely, and

went up again for another three-quarters of an hour. His courage and skill brought him great fame, and he was presented at court. He made many other successful balloon journeys before his death.

After these triumphs, as we should expect, longer and longer flights were made in balloons. One man flew 1,193 miles from France to Russia. Improvements were made in the balloons. A valve was put at the top of the gas-bag, so that some of the gas could be let out to make the balloon descend. Sand was carried which could be thrown out to make the balloon go higher. Thus the balloonist could choose, to some extent, the height at which he travelled; he could leave a current of air which was taking him in the wrong direction and try to find one that suited him better. But balloons have never been a satisfactory method of travelling; one is never sure which way they will go. No one has ever bought a balloon ticket from Cairo to Bombay.

The airship was a development of the balloon. As it was provided with engines, it could be made to go in any required direction. Unfortunately the hydrogen which kept it up was very inflammable, and many accidents occurred. Several enormous airships caught fire and were completely destroyed together with their passengers. Nowadays this type of machine has almost disappeared from the sky, being considered too dangerous for practical use.

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It is the aeroplane that has conquered the sky. The fundamental difference between the aeroplane on the one hand, and the balloon and the airship on the other, is that the aeroplane is heavier than air. It flies because of its motion; if it stops moving, it falls. Boys at school make

darts of paper which work on the same principle. If the dart is thrown by the hand it will fly across the room, but if it hits the wall and stops moving it falls to the ground. A kite, too, will remain in the air if a boy holds the string and a good wind is blowing; but if the wind fails, or the boy lets go of the string, the air ceases to pass under the kite to support it, and it falls down.

Men started to make machines on this principle. At first they made gliders, which are aeroplanes without engines. To begin the flight, the airman had to take off from some high place and glide down to a lower one; or the glider was pulled by a rope which was afterwards dropped. Many successful flights were made in gliders, and the next thing to do was to fit an engine to one and see if the machine could fly without other help. Steam-engines were first tried, but they were too heavy to be of any real use. One such machine, made in 1884, consisted of a large number of wings one above the other and was driven by a steam-engine. It is said to have risen for a moment off the ground. Another rose, but fell and was damaged. It was not until the internal combustion engine, which is very light for the power it develops, was fitted to a machine that any real success was obtained.

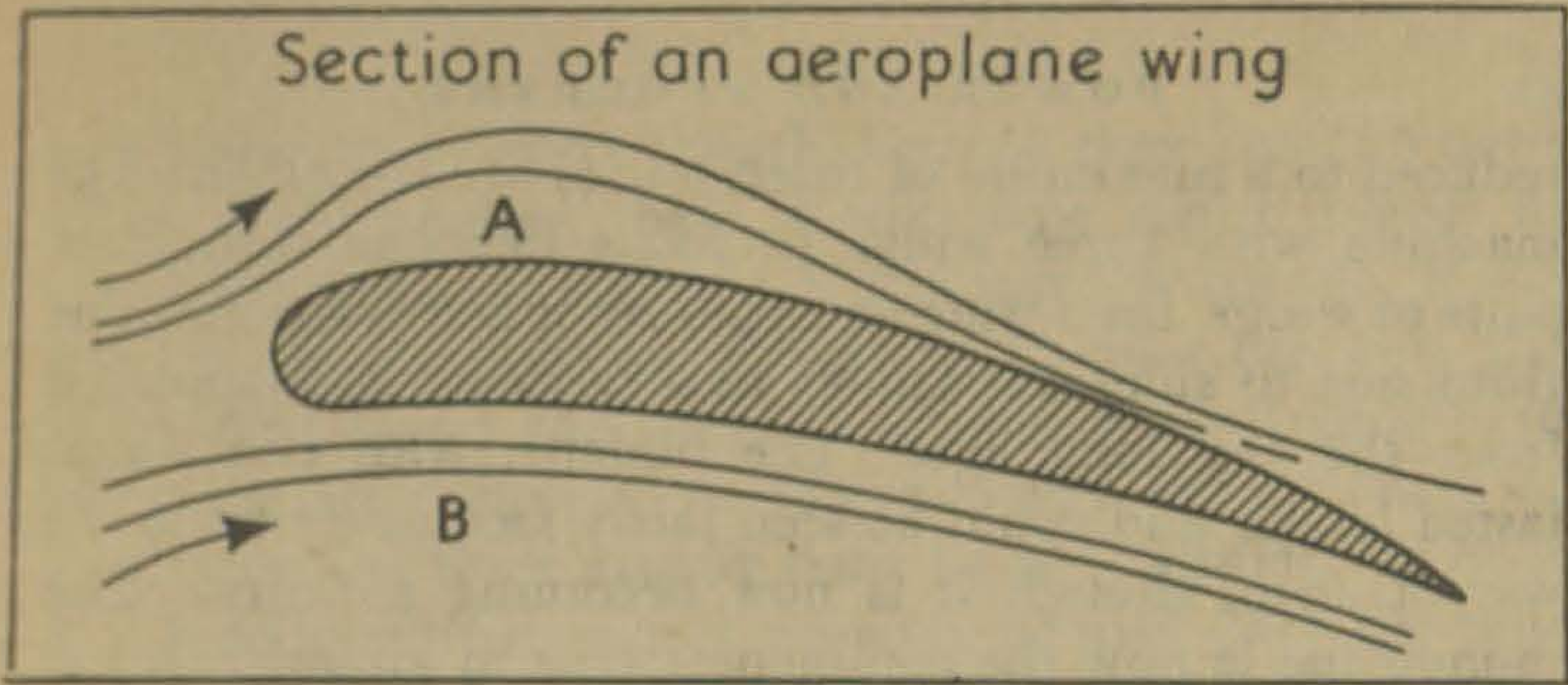
On December 17, 1903, Orville Wright, an American, flew safely in a heavier-than-air machine for twelve seconds. He and his brother Wilbur had made a lot of experiments and had taken immense trouble to study the art of flying in gliders before they attempted to fly their aeroplane. Orville came down safely after the first short flight, and on the same day the experiment was repeated three times. The longest of these flights covered a distance of 852 feet and lasted 59 seconds. The machine which was used had an engine developing only sixteen horse-power but the aeroplane reached a speed of 35 miles an hour. The two

brothers continued their experiments after their first success, and in 1908 Wilbur gave some exhibitions of flying in France which astonished all who saw them.

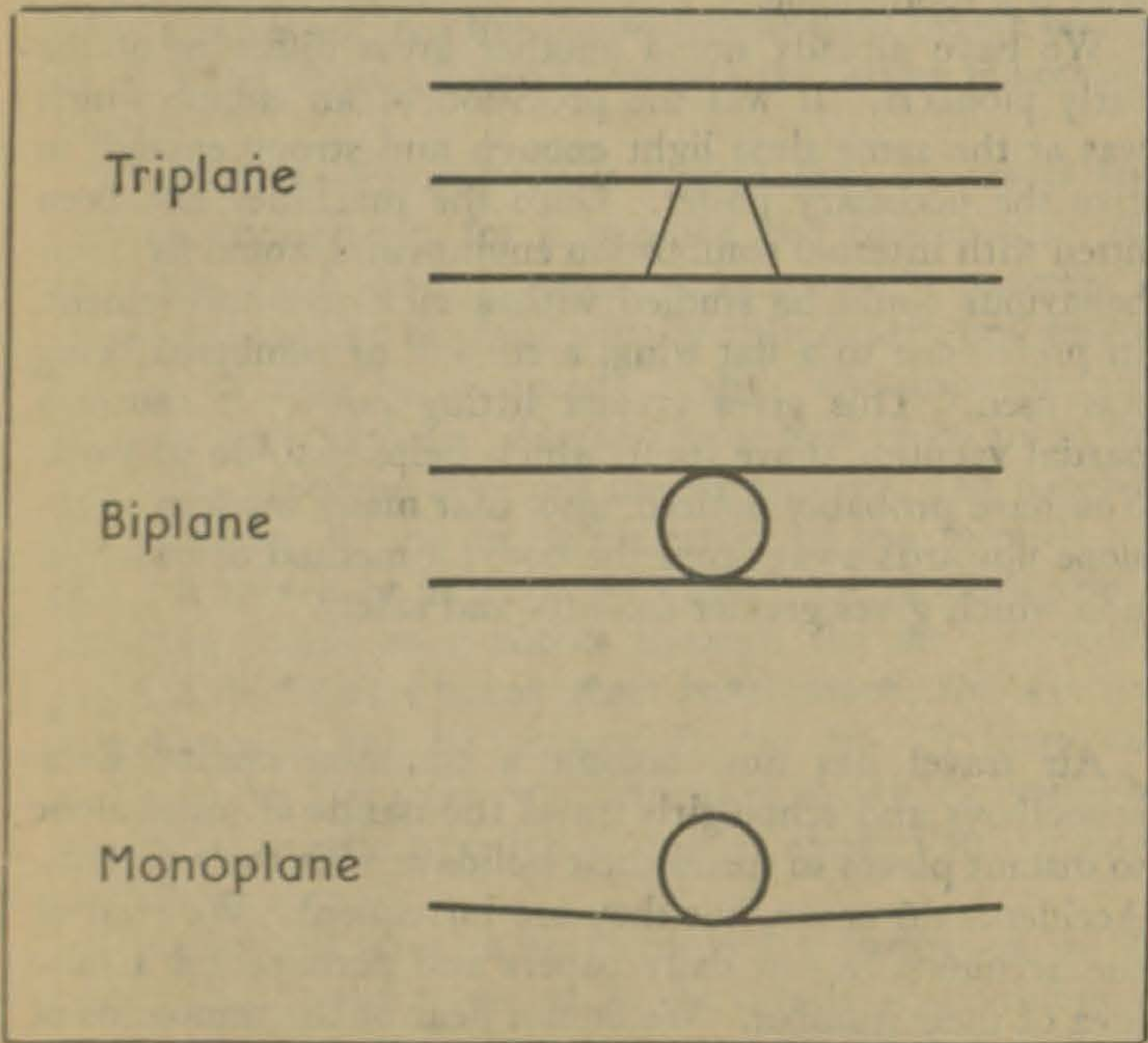
The Wright brothers laid the foundation of modern flying. Soon others followed in their footsteps. Louis Blériot, a Frenchman, flew across the English Channel from Calais to Dover in 1909. Prizes were offered for flights from one place to another. Competition increased. The aeroplane improved more and more as its behaviour became better understood. More powerful engines were developed. In 1919, Sir John Alcock and Sir Arthur Brown made the first flight across the Atlantic Ocean, and in the same year an aeroplane flew from England to Australia. The age of air travel had arrived.

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What were the difficulties which the early pioneers had to overcome in making successful aeroplanes? One of them was to decide what general system ought to be used. Naturally, the first idea was to use wings as birds do, and we have seen how some men actually provided themselves with wings fastened to their arms, and how they failed. It is an interesting fact that when men try to do the same things as nature does, they usually have to do them in a different way. Carriages, trains and motor-cars use wheels instead of legs; aeroplanes have fixed wings, unlike those of birds; boats are moved by oars or the wind, and ships by paddle-wheels or screws, though not one of these methods is used by any fish. In general, too, the wheel, a necessary part of most machines, never appears in nature. Thus the decision to use a fixed wing was one that had to be made before any aeroplane could fly satisfactorily. Some of the early machines had a lot of wings of various sizes and in different positions. The number was soon



The wing of an aeroplane, in section, resembles that of a bird. The speed of the aeroplane through the air creates a strong wind. Air, flowing over the wing, rises and creates a partial vacuum at A, thus sucking the wing upwards and giving " lift ". Air flowing under the wing at B pushes the wing upwards. The " lift " at A is just as great as the " lift " at B.



reduced to a maximum of three, one above the other. The machine with three wings (it looks like one with three pairs of wings, for a wing stretches right across the machine from side to side) was known as a triplane; it disappeared from the sky long ago. The biplane, with two wings, lasted longer and could be seen fairly frequently up to the war of 1939, though it is now becoming a rarity. The monoplane is now the commonest type of aircraft. It has the advantage that it presents less resistance to the air than other types, and can therefore fly faster with the same power. If you visit one of the big commercial aerodromes at the present time, you will notice that nearly every aeroplane coming down to land or taking off for distant countries is a monoplane.

We have already noted another great difficulty of the early pioneers. It was the provision of an engine which was at the same time light enough and strong enough to give the necessary power. Once the machines had been fitted with internal combustion engines and would fly, their behaviour could be studied with a view to improvement. In preference to a flat wing, a curved, or cambered, wing was used. This gives greater lifting power; it causes a partial vacuum above itself, which helps it to do its work. You have probably noticed, also, that many modern wings slope upwards away from the body, a method of construction which gives greater stability and safety.

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Air travel has now become a common event. Even schoolboys and schoolgirls travel thousands of miles alone to distant places to spend their holidays with their parents. Accidents dō occur, but they are infrequent. We read of the accidents in our daily papers and perhaps get a false idea of their number. We do not hear of the thousands of

safe flights made every month, because they have no news value. Nevertheless, there is still some slight danger in travelling by air, as there is in any form of travel. If the engines fail, the only way in which the pilot can keep the air rushing under the wings to support the machine is to point the nose slightly downwards, and let the force of gravity do the work usually done by the engines. If he is at a good height when this happens, he may have the time and the luck to find a suitable place to land, and so avoid any serious consequences. But if the engines fail when the aircraft is taking off, a crash can rarely be avoided; there is no time to do anything about it. Therefore the engines are kept in the best possible order, and tested again and again If you have travelled by air, you may have noticed that the pilot races his engines for a considerable time before taking off, to warm them up and to be sure that there is nothing wrong.

What of the future? It is certain that air travel will increase enormously, for it is quick and convenient. An aeroplane needs no long roads or rails for its journey; it crosses the sea and the land equally well; deserts and forests are no obstacle to its speedy flight. Development and improvement are sure. Already some new types are in the sky. The jet-plane does not use an airscrew, but depends for its power on the forcible ejection of gas towards the rear. It travels at an enormous speed and often makes a whistling sound as it shoots through the air. It seems possible that before many years have passed, the airscrew will disappear and be replaced by the jet. If Hero, the maker of the first steam toy, were alive to-day, he would be pleased to see the principle of his jet applied to the most modern of aircraft.

Dangers will have to be faced in the future, as in the past. One of the foremost in the minds of inventors in

recent years was connected with the speed of sound. Sound travels through the air at about 1,100 feet per second, or about 760 miles per hour. It was feared that aircraft might be unable to go faster than sound, but by 1949 both British and American pilots had flown faster than the speed of sound. In the same way, courageous men will face the dangers of the future.

CHAPTER VI

Mass Production

"A GREAT mass" of something means a great amount. When the new method of manufacturing articles in great numbers was introduced, a new name was wanted for it and "Mass production" was the one that came into use.

In what ways does mass production differ from the older methods of manufacture? Formerly a craftsman, or skilled workman, often made the whole of an article himself by hand. He put into his work all his skill, all his experience. He was proud of the fruits of his labour. His reputation, his standing among his fellows, depended on his skill and on his character. He would have been ashamed if any serious fault had appeared in his work. He was envied and admired by fellow-craftsmen whose skill was not equal to his own. Articles made in this way could not be mass produced. Each article differed slightly from the others; in every one there was something of the maker's individuality. The finished article was sold at a high price, the price representing the time and the skill of the craftsman who had made it.

Many such articles, made long ago with loving care, possess a quality and a beauty that mass-produced goods cannot equal. The wonderful pottery of ancient China, the lovely carpets of Persia, the engraved swords of Damascus, the silver-ware of the Middle Ages—all these things show the individual craftsmanship of their long-dead makers.

These articles were made for the rich and for those who were moderately well off. The poorer classes could not hope to possess works of art. Their household utensils, their clothes and their farm tools were roughly and cheaply made, though very practical in serving the purposes for which they were designed.

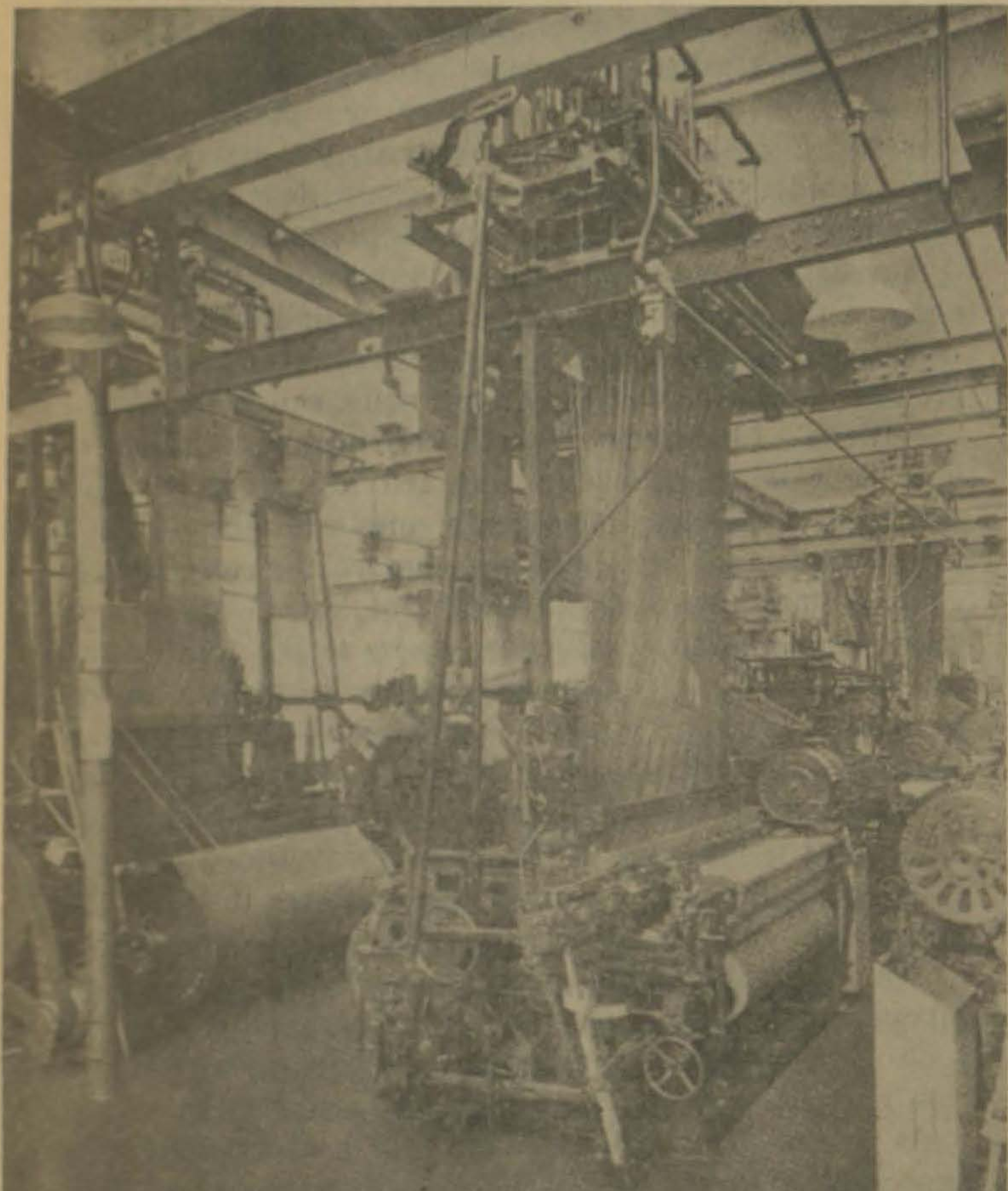
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The industrial revolution saw a great increase in the population of Europe. These people wanted goods, tools, clothes, houses, and all the things that make civilized life possible. The goods which they wanted had to be fairly cheap, cheap enough to be purchased out of the wages earned in factory or workshop. There were no restrictions on the manufacture of goods as there are in time of war, and each factory competed with its rivals in finding markets for its products. The demand for goods was great, both at home and overseas.

In deciding which goods to buy everyone is influenced by two considerations, price and quality. The ever-increasing demand was for goods of high quality at low prices. That factory and that country prospered whose goods competed successfully with its rivals as regards quality and price.

In the nineteenth century, the desire to produce high-quality goods at a low price led to what is now called mass production. The phrase nowadays is especially associated with the name of Henry Ford, who so successfully applied mass-production methods to the manufacture of motor-cars. His business rivals were quick to imitate him, thus proving the truth of the old proverb, "Imitation is the sincerest form of flattery."

But Mr. Ford was by no means the inventor of mass production. It is difficult, indeed, to say who was. When



(By courtesy of Ashton Bros. & Co. Ltd., Hyde)

Inside a cotton-mill

the first large mills for the manufacture of cloth were built, then we may say that mass production began. The invention of the steam-engine gave manufacturers the cheap power which they needed. Brilliant men perfected cotton gins and looms. When one huge machine began to perform rapidly the operations previously done slowly and laboriously by hand, the age of mass production was born.

A visit to a stocking factory is an interesting experience. One sees seven or eight huge, complicated stocking machines being tended by a single skilled worker. They are so complicated that only a mechanic can follow all the operations. Hundreds of wheels are turning, hundreds of fine, delicate threads are being fed into each multiple machine. Each machine manufactures a number of stockings at the same time, and you can see the stocking legs coming out of the bottom. When the leg is long enough, the machine automatically changes its method and begins to knit the foot. The operator's duty is to keep an eye on the machines, to mend broken threads, and to discover the cause of any stoppage. He has, in fact, only to keep the machine at work and to take away the finished article. The result is that the public, in ordinary times, can buy goods at a low price. A woman is poor indeed if she cannot afford to buy a pair of stockings

The price of any article depends chiefly upon the cost of labour and raw materials, though there are other expenses such as those of advertising and transport. Mass production has reduced the cost of labour to a minimum.

As new methods are invented and new manufacturing processes developed, output increases more and more. The aim of every manufacturer is to reduce costs and increase output.

Most of the articles of everyday use are mass produced. The buttons on your coat, your shoe-laces, pens, pencils

and exercise books are all good and cheap because they are mass produced. Cigarettes, to which most men and many women are willing slaves, are manufactured and sold by the million. Tobacco and paper are put into one part of a machine and endless cigarettes emerge at another. The long rolls of paper-covered tobacco are cut up into the right lengths and a moving belt carries them away. Another machine counts the cigarettes and packs them into boxes. From the time when the tobacco is put into the machine until the purchaser opens the box, no hand touches the cigarettes.

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In every factory that assembles complicated articles by mass-production methods, there is a conveyor belt. As its name shows, this is a moving belt which conveys, or carries, the articles to the workers. Each worker stands at a bench, and as the belt moves past him he takes from it the article that is being made. He performs one operation, and only one. He therefore becomes very skilled at doing this, and does it quickly. When he has done his job, he puts the article back on the belt and picks up another, which he treats in exactly the same way. This is an extremely efficient method of manufacture; for the worker need not go and fetch his materials, and no one has to bring them to him. Thus no time is lost. Even stupid workers can be taught to do just one operation. The result is that a complicated article is assembled speedily and economically.

The conveyor-belt method is used in most motor works, even when an actual belt is not used. The chassis, or frame of the car, is taken from a heap. A gang of men, perhaps four on each side, quickly attach wheels to it taken from another heap near them. When the wheels have been put

on, a boy pushes the chassis farther down the workshop to another gang of men who perform another operation. Above their heads is a kind of overhead railway which brings to them a heavy part of the engine. As it comes down, they guide it into its place in the chassis, put in the bolts, tighten the nuts and send the chassis farther on to another gang. Each gang does only one operation. At one place the whole body of the car comes down from above and is fixed into place. In turn the radiator lamps, battery and electric wiring are all fitted by expert workers, all of them skilled in one branch of the work. What started down the assembly line as a bare chassis soon rolls out of the works a complete car ready for the road.

The work of the management must be extremely efficient. If the workers themselves do not have to think of everything, the management certainly have to do so. All the different parts of a car have to be in place at the different points of the assembly line at the right time. Since the work of each gang depends on the work just done by another, any failure at one point will hold up the rest of the assembly line; it will leave men with nothing to do, while dozens of half-finished cars collect at one spot, just as dozens of vehicles are brought to a standstill when for any reason a busy road in a city becomes temporarily blocked. Few manufacturers make all the different parts of a car themselves. One outside firm may supply the wheels, another the lamps, another parts of the engine. To ensure that all these different parts are ready at the right time and in the right place requires much forethought and planning. Only a clever man should apply for the job of works manager in a motor firm.

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What has been the result of the application of these



(By courtesy of Morris Motors Ltd.)

Mass production of the motor-car

methods to motor manufacture? In the first place, all our lives have been profoundly affected by the motor-car. Cities have spread outwards because people can now easily reach distant places of business. The town has discovered the country; and the country people have been enabled to move about and visit the town. Old people who expected to pass all their lives in one place have in the last twenty years travelled, mostly by bus, far greater distances than they ever travelled before. Much of the food of the cities is brought in by the motor lorry which is becoming a keen competitor of the railway. Millions of cars and lorries are already running on the roads of the world, and the number will tend to increase as methods of mass production improve.

Another example of mass production is the morning newspaper. To see huge printing presses turning out and folding tens of thousands of newspapers, all exactly the same and all faultless, is an experience which can never be forgotten. The printing press is one of man's cleverest inventions. The great machine seems almost alive: it does everything to the newspaper except write the original copy. It is this machine that brings the daily newspaper, with its pictures and its thousands of words, within the reach of the poorest of men.

The output of goods in large quantities profoundly affects the standard of living of the people of the world. The main duty of statesmen is to work for the welfare of their fellow-countrymen. Their efforts should be directed to improving the living conditions of the people, their housing, their clothing, their food and their wages. There is no reason why the standard of living should not rise continuously. America is the place where the standard of living of ordinary people is the highest in the world. A high standard of living means high consumption of goods

by the ordinary people, good housing and clothing, sufficient amusement, medical care for all, good schools and sufficient leisure to enjoy life.

In many countries, before the last disastrous war brought peaceful progress to a standstill, improvement in all these matters was continuous. For this rise in the standard of living, mass production was in large measure responsible. Yet, to-day, vast areas of the world are stricken with poverty. Countless millions are crying out for goods which they cannot buy, either because they are not available at all, or because they are too dear. The methods of mass production scientifically applied will, it is hoped, change this state of affairs and gradually improve the conditions of the people of the world.

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This system of manufacture is not, however, an unmixed blessing. Most really happy men get more satisfaction in life from their work than from their leisure. Nearly all of us are happier when we are actively engaged than when we have nothing to do. During the school holidays, after the first week or two, many schoolboys wander miserably in the streets seeking amusement. They are much happier when they are busy at school and interested in their work. Time flies when one is busy: it drags when one has nothing to do. One of the necessities of a happy life is an interesting job, not necessarily an easy one, but one that gives us the opportunity to use our abilities and demands the best that is in us. It is a serious criticism of mass production if we come to the conclusion that most of the workers get no satisfaction, except for their wages, out of their labour.

We have seen that many craftsmen of former days put their heart and soul into their work. In many cases they produced the articles themselves from start to finish. The

pleasure and pride which they felt in a well-made article cannot be equalled by the factory worker of to-day.

There are still some of these craftsmen in the world. Not everything is mass produced. Suppose we find in a village an elderly man who has done nothing all his life but make fine furniture. Suppose we see and praise his handiwork and order a fine chair from him. After some weeks have passed, he sends us word that the chair is finished and we go to take delivery of it. We praise the chair and pay the price. Then we take an axe and break the chair to pieces before the eyes of its maker. It is difficult to know what he would do. He would certainly be very sorry. He might even burst into tears at seeing the fruit of his skill and labour reduced to firewood in this barbarous manner.

Suppose then that we go to a motor works where a brand new car is awaiting us. We pay for the car and take delivery. Instead of driving away, we call together a number of the workers during the dinner hour and praise the car that they have made. We then take a tin of petrol and pour it over the car, strike a match and set fire to it. The assembled workmen would probably not care in the least. They might even laugh. They might suppose that an escaped lunatic had arrived at the factory. But nobody's feelings would be hurt by the stupid destruction of the article that they had made. Each worker contributes so little to the finished article that he does not think of it as the fruit of his own labours. His personal interest in it is very small indeed.

Workers who repeat the same operation day after day can take no pleasure or pride in their work. Their chief pleasure in life is outside the factory. Their work is dull, and they spend their time with one eye on the clock. It is realized that modern work is often dull, and in some fac-

tories a wireless set or a gramophone is turned on to provide music for the workers. The title of a common programme given by the British Broadcasting Corporation is "Music while you work." This provision of entertainment while the factory wheels are turning does not cause the work-people to neglect their duty; on the contrary, it increases output. In spite of various attempts to brighten the lives of the workers, however, the average man in a factory is rather to be pitied than envied. The dullness of his life is one of the drawbacks of mass production.

Some people consider that man is becoming the slave of the machine. Certainly machines are playing an ever-increasing part in our lives. Let us hope that they will never become more important than the men they were invented to serve. Charlie Chaplin, in his film "Modern Times," drew attention to this danger. In the film he got a job in a factory that employed mass-production methods. He had to stand by a machine with a spanner in his hand. An endless belt passed in front of him carrying slowly an endless line of articles. As each one passed, he tightened one nut on one bolt with his spanner. His work was done with one turn of the wrist repeated throughout the day. Very soon his mind became affected and the film shows the amusing things which he did as a result of his mental disorder. Although it was very funny, the film had a serious side. It showed that the kind of work which many people do, far from giving them pride and pleasure, is more likely to fit them for the lunatic asylum.

We must all hope that means will be found to retain the advantages arising out of mass production, while at the same time giving the worker some of the pride and pleasure of the old craftsmen.

CHAPTER VII

Signals and Signalling

WHEN a friend of yours is too far away to hear your voice, and you want to tell him to do something or other, you wave your arms and make signs in various ways. You are attempting to signal to him. Unless he is a highly intelligent person, he will quite probably misunderstand you and do the wrong thing. In order that a system of signalling may be satisfactory, its details must be arranged beforehand, and each end, the sender and the receiver, must know the signals that have been arranged.

It was the custom in the past, when news of some great event was expected, to light a fire on a hill which could be seen for miles around. The sight of the fire informed all who saw it that the event had taken place. Perhaps a battle had been won; the first beacon, as it was called, was lighted; watchers on distant hills saw the fire and lighted another which could be seen farther away; another followed another, until the whole country had learnt the good news. This ancient way of sending news of victory was revived in 1919, when the peace treaty after the first world war was signed. Beacons were prepared on hills round the coasts of England. One night at the end of June, watchers waited on the coastal hills and looked for the far-away fire. As soon as it was seen they lighted their own beacon, and passed the news on to the next signal point. In this way the signal fires circled the coasts of England, giving the good news that the war was over. Of course, in this case

the news was already known, and the beacons were lighted only as a pleasant revival of an old custom in an old land. Yet this used to be a common way of signalling by night, just as smoke was used by day.

When, as often happened, the old methods of signalling could not be used, messages were usually carried by hand from one place to another. Men who could run fast were chosen for the work, unless a horse and rider were available. Runners would arrive at their destinations completely exhausted by their exertions, and if the news which they brought was bad, they often had their heads cut off for their trouble. How often do we read in old books of the horseman who rode furiously through the night, changing horses when he could, bearing important news to the anxious people waiting in some distant town! This way of sending messages seems to us slow and clumsy, though the rider himself no doubt thought he had done very well.

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Signalling has always been important on the sea, not only to send messages from one ship to another, but to keep vessels out of danger. The old Pharos at the entrance to Alexandria harbour, built about 300 B.C., was probably one of the first lighthouses in the world and had a fire on the top to show ships their position. When ships passed one another on the sea they needed some way of communication, and flags were flown from the masts, high up where they could be seen by the captain of another vessel. This method of signalling is used nowadays, too, for it is a very convenient way of sending a message to a ship that is fairly near. It is also advantageous in time of war, when wireless silence must be maintained. If a wireless signal is sent, the enemy may pick it up and discover the position of the vessel sending it; but flags are silent. These flags are

of different shapes and colours. It is possible to spell out a message by using the flag alphabet, but usually a code is used. In this code one flag or group of flags mean a word, a phrase or even a whole sentence. There is, for example, a flag which means "Yes," another which means "No," and another which means "I have a dangerous and infectious disease on board."

Another way of signalling with flags is for a man to hold one in each hand and place his arms in a different position for each letter. At the receiving end one man watches him through a pair of binoculars and calls out the letters one after the other, while another man writes the message down. This is one of the things that Boy Scouts in every country learn to do. The semaphore, in which a post with wooden arms replaces the man and his arms, employs the same method.

When there is a fog at sea and the flags cannot be seen, signals may be sent with the ship's siren. Even if there is no special message to be sent, the siren's deep and unhappy voice continually pierces the fog to warn others of the ship's approach. The siren of a British ship in a fog must be sounded at intervals of not more than two minutes. When this happens, especially at night, nervous passengers long to be on dry land again; the voyage which seemed so pleasant and safe in the sunshine of a clear day now appears miserable and dangerous. In the thick blanket of fog surrounding the ship, the long deep notes remind the passengers of the constant danger of collision. Even if no other ship is near, and no answering sound is heard, many anxious people imagine that the vessel is heading straight for the rocks. Yet the use of the siren ensures that if two ships are near each other in a fog, the captains will be aware of the fact.

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The use of sound and of flags for signalling has been going on for a long time. The invention of the electric telegraph in the nineteenth century, however, revolutionized the methods of sending messages on land. The new invention depended on the fact that if a current of electricity is passed through a coil of wire surrounding a piece of soft iron, the iron becomes a magnet. As soon as the current is cut off, the magnetism practically disappears. Closely connected with the development of the telegraph is the name of Samuel Morse. Morse was an American painter, not at all the sort of man we should expect to invent an electrical instrument. He went to Europe to see and study the famous paintings there. When he was on board his ship returning to America, he met a man who was interested in the electro-magnet, and Morse soon saw that it might be used for sending messages. If two wires were attached to the ends of the wire forming the coil of the magnet, and a current was sent from a distant place through these wires, the magnet would indicate the presence of the current by attracting a light piece of iron, and the message might be read. When Morse arrived home he intended to make experiments on the telegraph, but he had so little money at the time that he had to go on painting to earn his living. Later on, however, he was able to devote himself to his scientific experiments and at last produced an instrument that worked. Like most inventors, he had to overcome many practical difficulties before success was achieved. One of these was the fact that the electric current was too feeble to work his magnet after it had passed through miles of wire; the resistance of the wire reduced the strength of the current, and the longer the wire, the greater was the resistance. He invented an instrument called the relay to deal with this problem. The relay is a magnet worked by a weak current. It attracts a

piece of iron and the movement thus caused is used to connect another battery in the circuit. The relay may be placed at any point between the sender and the receiver; it receives the weak signal and sends on a strong one.

Morse also invented the Morse Code which to-day is used all over the world. This is a system of dots and dashes, or shorts and longs. Different arrangements of these indicate different letters of the alphabet, numbers, punctuation signs and so on. The ordinary letters in the Morse Code are as follows:

a .—	n —.
b —...	o ———
c —.—.	p .——.
d —..	q ——.—
e .	r .—.
f ..—.	s ...
g ——.	t —
h	u ..—
i ..	v ...—
j ———	w .——
k —.—	x —..—
l .—..	y —.——
m ——	z ——..

There are also other groups for letters with accents or other signs on them. The letters *e* and *t* have short signs because they occur very frequently.

Though it was invented for the electric telegraph, the Morse Code is used in many other ways in the modern world. It may be employed to send messages at sea in the darkness by means of the signal lamp. It adds to the interest of a sea voyage if you can read the Morse Code; for then you will be able to understand messages that are

flashed to the ship from the shore or a passing vessel. To take an example, when you pass Gibraltar at the western end of the Mediterranean Sea, you may see a light spelling out the question, "What ship?" The ship will reply, giving its name, and the news that it passed Gibraltar at that time will be sent to the owners and the insurance companies, and may also appear in the daily papers. When two ships pass in the night, they communicate with the Morse Code flashed by signal lamp. They may often give each other valuable information in this way about fog, ice and so on; for each is approaching the area that the other has left.

Before Morse died, thousands of miles of telegraph wire stretched over the surface of the earth. Nowadays there are millions of miles of it. All railways use the telegraph to announce the movement of trains from one signal-box to another. Towns in nearly all countries are connected together by the post-office telegraph system. Cables under the sea link country with country; some of these cables, such as those under the Atlantic Ocean, are thousands of miles in length. Rapid communication over great distances is now a commonplace. In fact, it is quite possible for a message handed in in London at eleven o'clock to be delivered in New York at ten o'clock. It has not arrived before it started, but the clocks in New York show an earlier hour than those in London and so the message appears to arrive in less than no time.

You will have heard of other inventors who worked on the electric telegraph. Morse's name is well remembered because everyone has heard of the Morse Code.

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The invention of the telegraph made it possible to send a message from any one fixed position to any other; but it

could not be used between two moving ships, or between a moving ship and the shore. This was, however, rendered possible by the invention and development of wireless telegraphy. One day a German scientist called Hertz was making experiments in his laboratory with an electric spark coil. While the coil was at work producing powerful sparks, Hertz was called away for some reason and he left the laboratory without turning off the coil. On his way back he noticed that a single circle of wire, which had a small space between its ends, was producing sparks between them. The big coil was affecting the small one, although they were not connected in any way that he could see. When he stopped the big coil, the sparks in the small one stopped too; when he restarted it they began again. This may perhaps be called the origin of wireless communication.

Attention was drawn by this discovery to the fact that electric sparks caused some kind of radiation which could be picked up in another place. This radiation is supposed to consist of waves in the ether. What is the ether? That is a very difficult question to answer. To explain how waves of light reach us from the sun and the stars, we have to say that they are waves in something; they cannot be waves in nothing. They are obviously not waves in the air, for the air does not reach to the sun or even the moon. We therefore say that they are waves in the ether, something that is supposed to exist everywhere and in everything throughout the universe. It is only right to add that some scientists do not believe in the existence of the ether; and that a famous experiment[1] carried out to measure the speed of the earth through the ether gave the answer as zero, and always gives the same answer.

Hertz, however, was not especially worried as to whether

[1] The Michelson-Morley experiment.

there was an ether or not. He was excited about his discovery, and moved the single coil to different places to see if it would spark everywhere. He soon found, however, that if it was far away from the spark coil no result could be seen. It was a poor detector: it would not detect the presence of radiations very well.

The search began for better detectors. The best of the early ones was the crystal. It was found that certain crystals would detect the waves in the ether, and then a sound could be heard in a telephone receiver connected to the crystal. Thus the Morse Code could be used to send wireless messages.

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By this time, the attention of many great men had been attracted to the new science, for its enormous importance was obvious. If messages could be sent without wires, ships far out at sea would be able to communicate with land. Captain and passengers would no longer be cut off for days or even weeks from their fellow men. In case of storm and shipwreck, help might be summoned from any other vessels in the neighbourhood. Nobody doubted what a blessing this would be, but there were many who refused to believe that wireless communication could ever become a practical possibility.

Among the men who were by this time making experiments was Guglielmo Marconi. He was an Italian, but because he had family connections in England he took his early inventions there and soon attracted the attention of the navy, the army and the post-office. By the end of the nineteenth century, wireless communication over about 200 miles had been successfully achieved.

After some successes in England, Marconi thought he would try to send a wireless message across the Atlantic

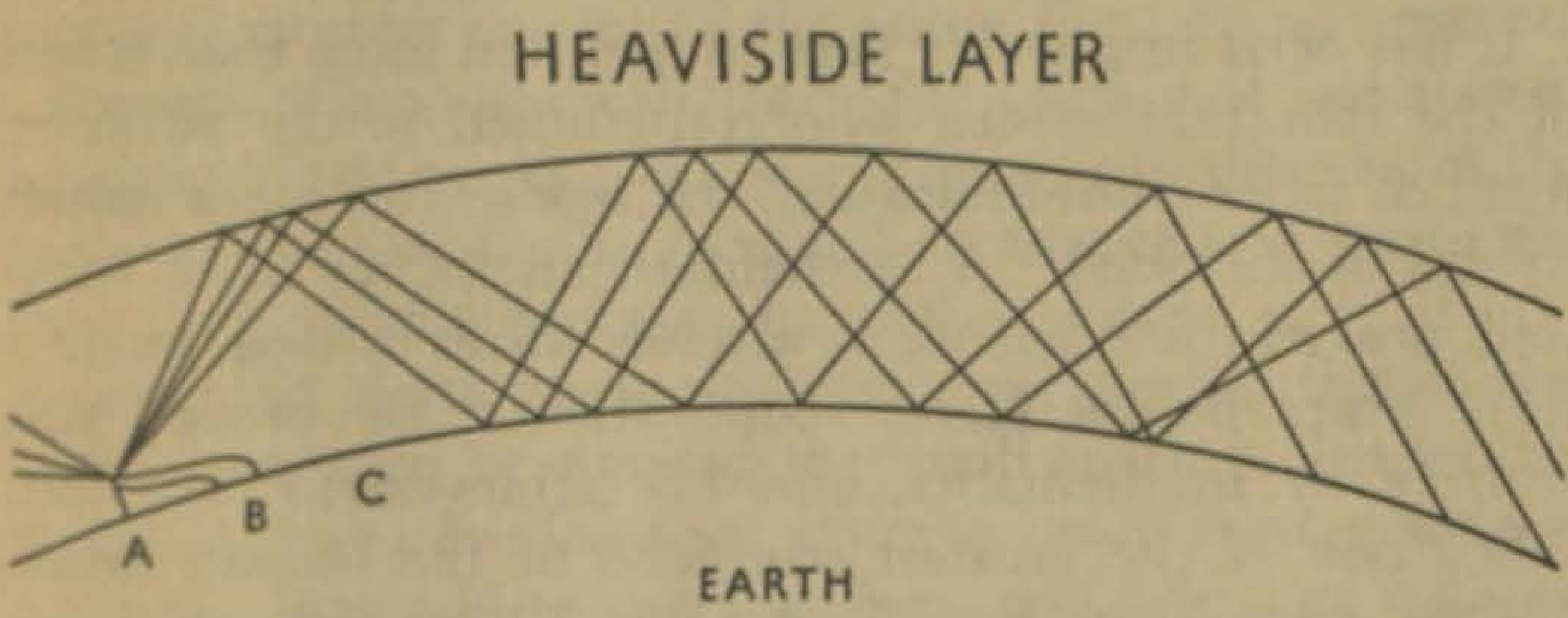
Ocean. If he could do this, those who were shaking their heads might begin to nod them. It would be not only a scientific triumph, but also a splendid advertisement. As a pioneer, Marconi had many bold ideas, but this was surely the boldest of all. We must remember that one cannot draw a straight line from England to America without making it pass through the water of the ocean. The surface of the earth is curved. At least one scientist of the time was certain that Marconi would fail; he felt that the wireless waves would go off into space, and never arrive at the other side of the Atlantic round the bend. A mountain of water a hundred miles high was in the way.

There was at this time a wireless transmitter at Poldhu in the south-west of England. Marconi arranged that this station should send out the letter S in Morse (. . .) on December 11, 1901, and the following days at regular intervals. He then crossed the Atlantic with two assistants to Newfoundland, taking his receiving apparatus with him.

In Newfoundland Marconi at first attempted to support his aerial wire by means of balloons, but he was unable to control them and he had to give up the idea. He finally succeeded in supporting it by means of a kite, connected it to his receiving apparatus, and started to listen for the three dots of the letter S from Poldhu. On December 12, 1901, he suddenly handed the receiver to Kemp, one of his assistants, and asked him whether he could hear anything. Marconi thought that he had heard the faint signal. After Kemp had listened for a short time he confirmed the great news. The first wireless signal had been successfully sent across the Atlantic Ocean!

How did the waves go round the bend? How is it that radio signals sent off in Australia can be heard in Egypt, half-way round the world? The explanation is to be found in the state of the atmosphere miles above the surface of

the earth. It is in a peculiar electrical condition[1] and causes waves to be bent downwards again after they strike it. Some are reflected as a mirror reflects light, and some are refracted or bent. Thus, waves which would otherwise travel off into space come back again to the earth and may be picked up by a suitable receiver.



How radio waves go round the world. A is the transmitter. B is the ground wave, the wave that goes along near the ground; it does not get very far. Other waves go upwards to the layer of electrified air (called the Heaviside layer because it was discovered by Heaviside) and are reflected or refracted downwards again to the earth. At C, no signals will be heard, because the ground wave does not reach this place, and the reflected wave passes it. The layer is not fixed and smooth, but changeable. Therefore the number of waves coming down at one place is always changing. This explains why signals being received from a distant station are sometimes strong and sometimes weak.

When the first transatlantic wireless signal had been heard, the new science advanced rapidly. To it we owe the comparative safety of ships at sea; when a ship is in difficulties, wireless signals soon summon other vessels to its aid. Many lives have been saved in this way. Daily newspapers, too, may now be published on board ship, for the wireless news can be picked up there as easily as on the land. Wireless has brought us all a new source of pleasure and amusement. We may sit at home and listen to great

[1] It is ionized.

music played thousands of miles away; or, if we feel so inclined, we may turn off the music and listen to a play or a short story. By means of the new science of television, a further development of the use of electro-magnetic waves, we can now see as well as hear the musicians or other performers in the distant studio.

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It has been impossible here to mention more than a few of the remarkable men who contributed to the advancement of radio communication, but one or two other names should be included. A mathematician, James Clerk Maxwell, proved the existence of wireless waves in 1864, twenty-three years before Hertz found them. He proved this entirely by mathematics, and his achievement has been called one of the greatest triumphs of the human mind. Let us remember, too, J. Ambrose Fleming, who first showed the use of the valve for wireless purposes, the valve which is now a necessary part of every transmitter and receiver; and Baird, the tireless pioneer of television.

One last development of this remarkable science may be mentioned. This is the discovery and use of radiolocation, or radar, a method of finding the position of objects which we cannot see. In December 1931, some scientists of the British post-office were making radio tests and noticed that passing aircraft interfered with the radio signals. It was therefore clear that the aircraft were, in some way, reflecting the waves that were being sent out. This led to a new science which was of immense importance in the last war. By means of radar enemy aircraft could be found even when they were far away. The radio signals were sent out in a beam, and if they were reflected from a certain part of the sky, there was evidently some object there. As the position of all friendly aircraft was known, enemy bombers

were discovered before they arrived at their targets. The system was used by both sides in the war, though the most advanced country in the science was undoubtedly Great Britain. It is even possible that without radar, Britain might have lost the war. Now that the war is over, it is evident that radar is going to play its part in peace. A radar instrument placed at the front of a ship will show whether there is any object in its way; the radar eye will pierce that great enemy of the sailor, fog. It will prevent collisions at sea and will warn the captain if his ship is heading for the rocks. When anything is in the way of the radar beam, that fact is recorded on a screen on board the ship, and suitable precautions may be taken.

Little did Hertz know the wonderful possibilities he had originated when he noticed the small spark in his laboratory! A scientific discovery, however small it may seem at the time, may add to the happiness and safety of millions of people.

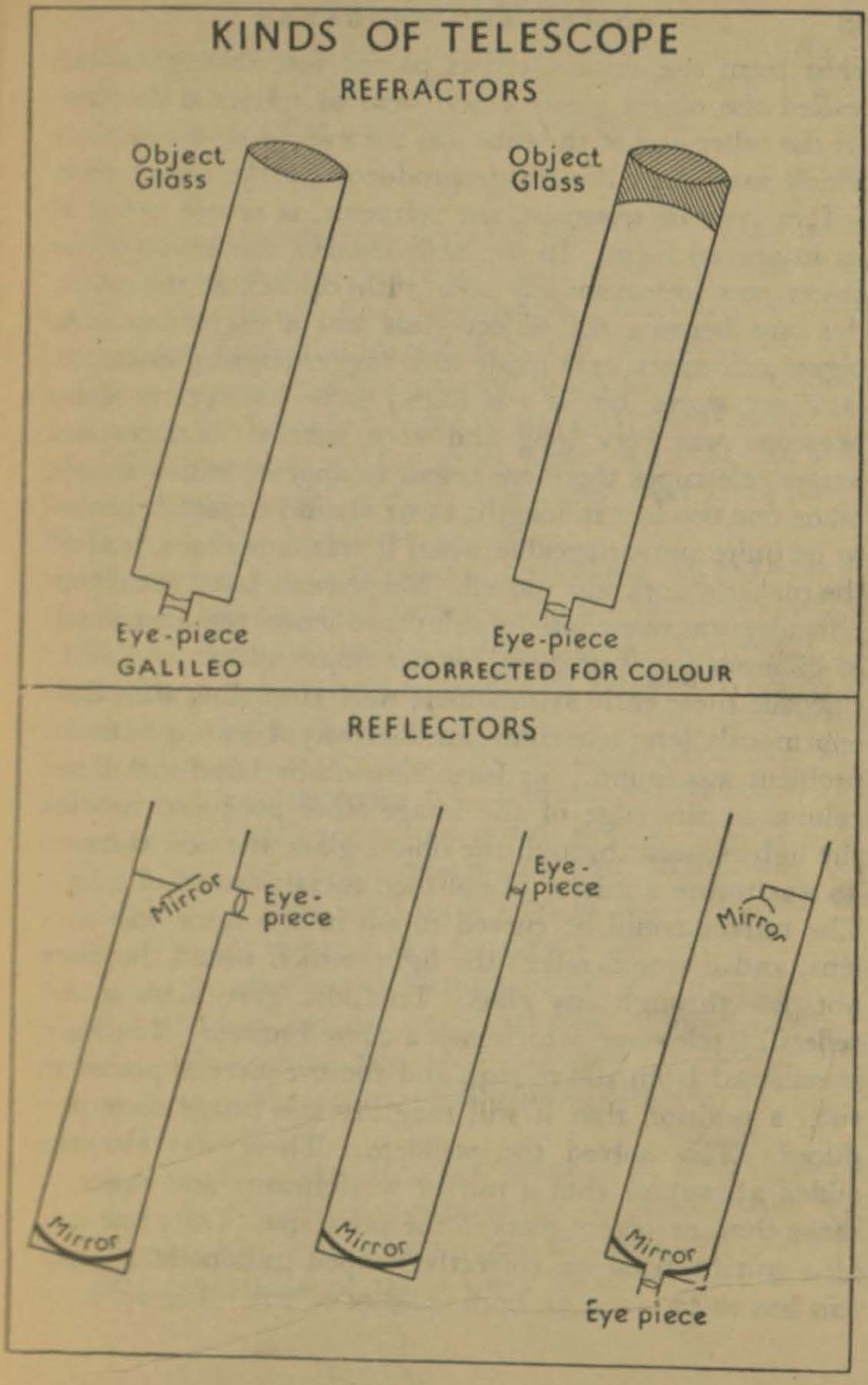
CHAPTER VIII

The Telescope

ONE day at the beginning of the seventeenth century, a spectacle-maker in Holland noticed that if he looked at distant objects through two lenses in line with each other, the objects seemed to be much nearer than they really were. The famous Italian scientist, Galileo Galilei, heard of this and immediately set to work to make an instrument based on this principle. When it was completed, his friends were surprised and delighted to look through it at trees and houses far away and see how near they seemed. Looking through the telescope, as the new instrument was called, became an interesting pastime. But Galileo himself was a scientist and had other ideas. He was not very interested in looking at distant trees, which you could examine equally well or better if you went to them. There were some things which nobody could visit or examine at close quarters. He turned his telescope on the moon.

Can we imagine the feelings of this great man when he saw mountains on the moon? New ideas began rushing into his mind. He looked at the sun through his little instrument, and noticed sun-spots moving across its face. This led him to the conclusion that the sun was turning round, or rotating, because the spots always moved in the same direction. By turning a telescope on the sky for the first time in the history of the world, Galileo opened up a new path in the advance of knowledge.

Galileo's telescope was what we call a refractor. The


KINDS OF TELESCOPE
REFRACTORS
Object Glass
Eye-piece
GALILEO
Object Glass
Eye-piece
CORRECTED FOR COLOUR
REFLECTORS
Mirror
Eye-piece
Mirror
Eye-piece
Mirror
Mirror
Mirror
Eye piece

light from the distant object passed first through a lens (called the object glass) which bent or refracted the rays. At the other end of the tube was the eye-piece, another lens which magnified the image produced by the object glass.

This type of telescope, the refractor, is in use to-day in an improved form. In the early models the image of the object was unfortunately seen with colours at the edges; this was because the object glass was a single lens. As bigger refractors were made with bigger object glasses, this fault got worse, but it was found to be less serious if the telescope was very long and very narrow. Longer and longer telescopes therefore began to appear, until someone made one 600 feet in length; as we should expect, it proved to be quite unmanageable when it was completed, and all the maker's work was wasted. Many years later, the colour difficulty was overcome by using two lenses together, made of different kinds of glass, for the object glass.

While these early astronomers were struggling with their enormously long telescopes, another way of dealing with the problem was found. Sir Isaac Newton declared that if the colours at the edge of the image were produced because the light passed through the object glass, the best thing to do was to use a mirror of polished metal instead of a lens. The mirror could be curved to act in the same way as a lens; and it would reflect the light, which would therefore not pass through any glass. This idea gave birth to the reflecting telescope, which uses a curved mirror. The light is reflected from the mirror, and the eye-piece is placed in such a position that it will magnify the image thus produced. This solved the problem. There was also the added advantage that a mirror was cheaper and easier to make than an object glass of the same size. Only one side of a mirror need be correctly shaped and polished, but this has to be done on both sides of a lens. The reflector

is so successful that it is still in use to-day. The largest telescope in the world is the Mount Wilson reflector in America, which has a diameter of 100 inches.

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What has the telescope done for mankind? Many books would be needed to give a complete answer to that question. It has given us our knowledge of the universe. It is true that, before the invention of the telescope, men had begun to observe the heavens and to notice what was going on above their heads. Some of the early ideas seem very foolish nowadays; on the other hand, some of the early observations made without telescopes were very clever indeed. Let us look back a little.

What were the early ideas of men about the sky and the earth? They naturally believed that the earth was motionless, and they also supposed that it was flat. These two ideas do not surprise us. Children nowadays think the same until they are taught differently. How were men to know that the earth was a ball circling round the sun? They had no telescopes for accurate observation. They had not travelled round the world; indeed, many parts of it in those days were unexplored and unknown. They thought that they lived on a kind of flat plate, and that the sky, with the sun and the moon and the stars, was a kind of inverted bowl turning round above them. The sun, the moon and the stars were their lamps for day and night. Everything was well arranged for their benefit; they were at the centre of all things; the universe existed only for them.

It was rather surprising, of course, that the sky did not fall on their heads. Everything else fell downwards. What held the sky up? And what held the earth up? Astonishing explanations of these two difficulties were invented.

The Hindus, for instance, believed that the earth rested on the backs of four huge elephants. The elephants were standing on a tortoise. The tortoise was swimming in some sort of enormous ocean. And what of the sky? The western peoples believed in the old days that it was held up by a giant called Atlas. He had to support this dreadful weight for ever as a punishment for fighting against the gods. We may laugh at these ideas now, but at any rate they show that men had begun to think about the universe in which we all live. They had begun to watch the stars, and soon they made one or two clever discoveries.

It is not so strange that the serious study of the stars should have begun in the countries of the Middle East. Where else in the known world did the stars shine with such brilliance from skies so little obscured by clouds? No doubt the heavenly bodies were studied in countries farther east too, but our knowledge of early astronomy comes from Babylon, Egypt and Greece.

Those of us who live in modern cities do not look up at the sky as often as men used to do in the past. We have less time to spare than they had; our attention is perhaps more fixed on worldly matters; and huge buildings cut off our view of the heavens. Long ago in the Middle East people probably stayed indoors during the middle of the day, for it was hot outside. But then, as now, it was the pleasant custom to spend the early hours of the night sitting in the open air to discuss the affairs of the day. This custom has been going on for thousands of years and will continue, no doubt, as long as the sun is hot.

As they sat thus, how often must the eyes of men have turned to the beauty and the brilliance of the night sky! What lengthy arguments and discussions must have taken place about the number and the size of the stars! We do not know who made the discovery, the amazing discovery,

that while most of the stars kept their positions from year to year, there were a few that wandered about along regular paths. What we do know is that this fact was known to the ancient people of Babylon. These wanderers, now called planets, were given names; and as they were thought to have an influence on the lives of men, they were named after gods and goddesses. The beautiful evening star that we know as Venus was, for example, called Ishtar, the goddess of love. These learned and observant men of ancient Babylon were the first astronomers in the world.

As time passed, early ideas began to change. Some of the early Greeks began to doubt that the earth was flat; and at least one great teacher, Aristarchus, said that the earth moved round the sun. He said this about 250 B.C., or about 1860 years before the invention of the telescope. How remarkable it is that such a discovery could be made by a man who had only the naked eye with which to study the heavens! Unfortunately, at that time no one was able to understand how valuable the discovery was, and it was forgotten.

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It was not until about four hundred years after this that a theory of the universe was worked out. It was developed by Ptolemy of Alexandria, and so it is known as the Ptolemaic theory. By this time the idea that the earth was flat had been abandoned, and it was rightly supposed to be a round ball. According to the Ptolemaic theory this earth of ours was the centre of the universe and everything else revolved round it. This is not our modern view but the theory worked so well, although it was rather complicated, that it foretold the future positions of the planets fairly closely. It fitted the facts so well, indeed, that it was not

seriously doubted for 1,400 years. That is a long time for a scientific theory to remain unquestioned.

By the sixteenth century, however, it had become clear that something was wrong. The planets were not quite in the positions that the Ptolemaic theory had foretold. Men began to search for a better explanation of the universe.

The sixteenth century in Europe was an adventurous and exciting time. New ideas were in the air. Columbus had just discovered America, Michael Angelo was painting his famous pictures in Italy; commerce was expanding; Shakespeare was born. Into this century of energy and new horizons was born a Pole, Nikolaus Copernicus. As a young man he went to Italy, where he studied various subjects including medicine and mathematics. While he was there he began to distrust the Ptolemaic theory; and when he went back to his own country (where he worked as a doctor) he found time to develop a new theory of the universe. He said that the earth and the other planets revolved round the sun. He also said that each planet rotated, or turned, on an axis, and that it was the rotation of the earth which caused the rising and setting of the sun and the other heavenly bodies.

This theory is almost the same as the one which we believe. Copernicus, however, did not publish it very widely until the year of his death. He knew that many people would not like it. New ideas are often disliked or distrusted, but this one was especially hateful to a lot of people. Men did not wish to believe that the earth was only a planet like the others; that it had no special importance; that it was not the centre of the universe. When the theory became widely known, a rather stormy discussion arose between the supporters of Ptolemy and those who believed that Copernicus was right. Ptolemy's theory

seemed more sensible, but the new one explained the movements of the planets better.

Then came the invention of the telescope. Among the objects in the sky which Galileo examined through his new instrument was the planet Venus. He noticed that it sometimes looked rather like our moon when it is not full; that is to say, part of the planet's dark side was facing him. As this was one of the results which would follow from the Copernican theory, Galileo said that Copernicus was right and Ptolemy was wrong. He found himself in great trouble for saying this. He was brought before an assembly of learned men, and was there compelled to admit that the earth did not move. He agreed to say this before the assembly but he went away muttering, "E pur si muove" (And yet it moves).

The chief difference between the Copernican theory and the modern one is this: according to Copernicus, the planets moved in circles round the sun, but we think that they move in ellipses, which are circles slightly flattened. In the past, men had a great respect for the circle. It seemed to them a perfect figure and therefore very suitable for the paths of heavenly bodies. It was not until some years after the death of Copernicus that the circle was given up as a necessity of planetary motion.

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The invention of the telescope led to enormous progress in the study of the heavens, and is chiefly responsible for our modern ideas of the universe. As we turn to these ideas, we must remember how much our knowledge has advanced since the time of Galileo, and we must be prepared for some surprises. Modern astronomical ideas are astonishing, and to some people incredible. For one thing, astronomers are able to measure the distances between the

different things in the universe. The measurement is not exact, but we can get a fairly good idea of these distances. Some of them are enormous. They are so enormous that astronomers long ago abandoned the use of miles and kilometres to express them. It means little to an ordinary man when he reads of a billion miles. A billion is a million million. He probably thinks that there is not much difference between a million and a billion; they are both huge numbers and mean rather a lot. Is there much difference? Let us take an example. A million seconds make about eleven and a half days and nights; a billion seconds make more than thirty thousand years.

The figures in which astronomers deal are so huge that the phrase "astronomical figure" has come into use in English to mean an enormous figure. To make it easier to discuss and compare the tremendous distances between the objects in the universe, it was decided to introduce a new unit of measurement called the light-year. A light-year is a *distance*, the distance that light travels in one year. Light travels a long way in a year, for its speed is 186,000 miles, or 300,000 kilometres, a second. If we say that a star is 100 light-years away from us, we mean that its light takes 100 years to cover the distance between us and the star; the light which enters our eyes when we look at it left it 100 years before.

Let us now consider the modern view of the universe. We will begin with the sun and its family, for this is comparatively small. The sun is a star. It looks bigger than the other stars because it is much nearer to us than they are. Light takes only about eight minutes to reach us from the sun, but the nearest star is about three light-years away. The sun is about 93,000,000 miles from us, and round it go the nine planets, each travelling in an ellipse one outside the other, and each prevented from escaping into space by

the gravitation of the sun. Two of the planets, Mercury and Venus, are nearer to the sun than we are.

Planets have no light of their own; they shine because they reflect the light of the sun. You will remember that Galileo looked at Venus with his new telescope, and noticed that it looked sometimes rather like our moon when the surface facing us is not wholly lit up by the sun. This proved that it is nearer the sun than we are, because if it were farther away we should always see its full shining face.

Outside the path of the earth round the sun comes the planet Mars. Mars has attracted more attention from the average man than the other planets. It can be seen fairly well sometimes. In 1887, when it was at its nearest position to us, the Italian astronomer Schiaparelli startled the world by saying that he could see straight lines on Mars, and he called them channels. The Italian word for channels is *canali*, and thus the idea arose that there were canals on Mars. Many other astronomers later thought they could see these straight lines, and were filled with excitement. If there were canals, was it possible that there were men, or some kind of living creatures, who had made them? These lines may not, in fact, be canals, but it seems possible that there is some sort of plant life on Mars. There are also white patches at the north and south poles in the winter, which may be ice; the white patches disappear in the long Martian summer, and this may show that the ice is melting. If there is water and plant life, is there animal life? No one can answer the question with certainty, but at least the existence of such life is doubtful, for Mars seems to be a very cold place with a temperature well below zero centigrade, and its air appears to be very thin.

The planet outside Mars is Jupiter, the largest of all. It has four large and five small moons, which revolve round it as our moon revolves round the earth. Next comes the

beautiful planet Saturn with its famous ring. This ring looks rather like a white gramophone record with its centre cut out. Inside it is Saturn itself. The ring was a puzzle to astronomers for a long time, but it is now believed to be composed of a large number of small bits of ice. Saturn has nine moons that we know of, and there may be a tenth.

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The five planets, Mercury, Venus, Mars, Jupiter and Saturn, have been known from early times. It was not until 1781 that the next one, Uranus, was discovered. A famous astronomer and maker of telescopes, Sir William Herschel, was examining some stars through one of his instruments when he caught sight of a body which he had not noticed before. After watching it for some time, he found that it had the motion of a planet and belonged to the sun's family. This body is now known as the planet Uranus, though Herschel gave it another name.

The study of the heavens had now advanced to such an extent that it was noticed that Uranus did not move exactly as it should in its journey round the sun. Some explanation of its irregular course was sought, and two mathematicians worked out the position of another planet which must be disturbing the motion of Uranus by its gravitational pull. These remarkable men were the French astronomer, Leverrier, and the English mathematician, Adams. When a telescope was pointed to that part of the sky which they had indicated, the next planet, Neptune, was found. What an astonishing example of the power of mathematics this was! In 1930 the last planet that we know of, Pluto, was also discovered as a result of mathematical calculation. Though much nearer to us than the nearest star, it is so very far away that we know little about it.

Thus there are nine known planets revolving round the

sun. There are other bodies also, but these planets form the most important part of the sun's family. Where did they come from? According to an old theory, they were once part of the sun and were torn out of it in a gaseous state by the attraction of another star which came near to the sun. But astronomers have now abandoned this theory and think that the planets were formed when another star, which was revolving round the sun, exploded violently. The explosion drove most of it far away into space, but small amounts of gas were left near the sun. This gas gradually cooled down into solid masses which broke up into pieces, forming the planets that we know.

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It is clear how much we owe to modern telescopes for our knowledge of the sun's family. They have not only allowed us to find new planets, but have given us such details as the number of their moons. There is another instrument called the spectroscope which is of great value to astronomers. If a ray of light, sunlight for example, is allowed to pass through a triangular piece of glass called a prism, the light is divided up into a band showing colours and lines. This band is called the spectrum, and the instrument for studying it is called the spectroscope. If light from different substances, glowing brightly at a high temperature, is passed through the spectroscope, it is found that every substance gives a spectrum that is different from all the others. Thus, by examining the spectrum, a scientist can say what substance is producing the light. Astronomers use this instrument to study the stars, and by doing this they can say what the stars (or, at any rate, the exterior parts of the stars) are made of.

When the sun was being examined in this way, a new element was discovered which had never been found on the

earth before. It was therefore given the name "helium," from the Greek word "helios" which means the "sun." Later on, in 1895, this element was also found on the earth. How great is the mind of man, which can design and use an instrument to find something new in the sun, 93,000,000 miles away across empty space, before it is discovered on our own familiar earth! The discovery of helium on the earth gave scientists great confidence in the spectroscope, because it showed that the instrument led to correct conclusions.

The spectroscope can do more than tell us what the stars are made of. It will also show whether the source of light is approaching or going farther away. We may remember that Galileo saw spots on the sun which made him think that it was rotating. The spectroscope proves that he was right, for it shows that one edge of the sun is always coming towards us and that the other edge is always going away.

The telescope and the spectroscope have greatly increased our knowledge of the universe. Most of the stars appear to be masses of gas, some smaller than our sun, some much greater. If the star Betelgeuse were placed where the sun is, for example, the earth would be inside it, because it is so big. It is impossible to say how many stars there are; one supposition puts the number at 10,000 million, but no one can count such a number. It is believed that they are arranged in a group, in shape something like an enormous round watch. The distances between the stars are far greater than the distances between the planets and the sun. Light takes eight minutes to reach us from the sun, but about three years to reach the *nearest* star. If you put a spot on a piece of paper to represent the sun, and another spot one inch away to represent the earth, you would have to go about three miles down the road to put the spot

showing the position of the nearest star. Other stars are much farther away still.

Is this mass of stars the whole universe? It is not. The telescope shows many other objects in the sky beyond the stars. These are the nebulæ. A nebula is a mass of gas, and it contains other stars. In size it is comparable to the mass of stars of which our sun is one. These nebulæ are far away in the vast depths of space, separated from us by distances that are too great to understand. They appear to be rushing away from us at tremendous and increasing speeds. Astronomers can see about 100,000,000 of them, and the nearest is about *700,000 light-years away*.

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Are we to believe that, in this enormous universe, there may be other worlds like ours with living creatures like us on them? It is clear that men could not live on the burning sun or on the hot stars. The answer to the question therefore depends, to a great extent, on whether the other stars have planets. We cannot see any, but then the distances are so great that we cannot expect to do that, for planets are small and have no light of their own. It is likely, however, that other stars have planets, and that the question cannot be narrowed down to the planets which go round the sun. We have seen that the birth of the sun's family may have been caused when a companion star near the sun exploded, and left behind small amounts of gas which cooled down and became the planets which circle the sun. Explosions of this kind seem to happen in space about once in every two or three hundred years, and it is believed that more than 10,000,000 of them must have happened since the origin of the first stars. By these explosions between 100,000 and 1,000,000 planetary systems may have been formed where conditions are or were suit-

able to support life. Some scientists even believe that creatures like ourselves, living on dry land and breathing oxygen, may now exist in other parts of space.

This is the latest theory about the origin of the planets and the possibility of life on them. But an older one suggested that planets were very rare objects indeed. Professor Eddington, in his book *The Nature of the Physical World*, said, "I feel inclined to claim that *at the present time* our race is supreme." The latest ideas, on the other hand, suggest that our race is not supreme at all.

CHAPTER IX

Medicine

THERE are people who take every opportunity of deploring the present age and regretting "the good old times" that are gone. Certainly life in the past seems to have been more leisurely than it is now. Money was worth more, and those who had it could easily procure what they needed. Undoubtedly life was pleasant for a small class of people, however unpleasant it may have been for the great majority. But life, if pleasant, was also likely to be quite short. "A short life and a merry one" seems to have been the motto of the well-to-do. "A short life and a hard one" would have suited the poor as a motto.

A man to-day expects to live many years longer than his forefathers did; a woman even longer. What is called our expectation of life has been, and still is, increasing. A hundred years ago it was much less. To-day epidemics are rarer, and less violent when they occur. Fewer babies die: more people reach old age. We enjoy healthier lives than our ancestors did, and we should be grateful to those who have taught us how to live, and whose researches have so greatly increased human happiness. The real benefactors of mankind are not the generals and politicians, but those whose labours have led to an improvement in the health and happiness of the common man. The better health of the people of to-day is due not only to doctors and their researches but also to a widespread improvement in living conditions. We are cleaner in our habits; our houses, fac-

tories and cities are far superior to those of our ancestors; and a knowledge of what to do and what not to do to maintain good health is more widespread than it used to be. Sickness has, to a great extent, lost its fears; we face our doctors with a smile on our lips and usually with no terror in our hearts. If we compare our lot even with that of our great-grandfathers, we should indeed feel grateful.

In the "good old days" doctors had no special training. A young man was apprenticed to a doctor and picked up what knowledge he could. When he was old enough, and thought he knew enough, he started to practise himself. The scientific knowledge of the best of them was meagre, their methods rough. Almost anyone with sufficient courage could practise surgery; the village barber was often the village surgeon too. Ignorance of the causes of illness led to extraordinary methods of treatment. In a large number of illnesses "bleeding" was prescribed. A vein was opened and a quantity of blood drawn from the patient. In England in the seventeenth century, a doctor called Sydenham thought he could cure nearly all cases of illness by bleeding; he never extracted less than eight ounces of blood, usually ten, and sometimes as much as forty! Others were particular as to which part of the body the blood should be taken from, and at one time it was considered important to choose the right day of the month to bleed the patient. No one knows how many deaths have been hastened by this drawing of precious blood. Nowadays this practice has almost gone out of fashion. How many of our friends have been bled? Probably none! On the contrary, many lives have been saved by blood transfusion, that is, by allowing blood from the body of a healthy person to flow into the body of a patient who has lost too large a quantity of his own. Blood for this purpose need not go directly from one person to another; it may be stored in bottles and kept

ready for the time when it is needed. People who offer to give blood to save the lives of others are called blood donors. Because they are strong and healthy, their bodies soon make up for the blood that they have lost, though they may feel rather weak for a short time.

In the days before the discovery of anæsthetics, various methods were used to keep the patient quiet during an operation. One way was to knock him senseless. During many operations, several strong assistants held the patient down while the surgeon did his best, or worst. Their methods were rough and ready. On the battlefield the surgeon might have to amputate a soldier's leg. The stump was then plunged into a bucket of hot liquid tar which stuck to the wound and stopped the bleeding.

In hospitals the doctors would go from one patient to another with the germs of deadly diseases on their hands without knowing it. Ordinary people hated hospitals and dreaded doctors, and no wonder. A sick person entering a hospital was quite likely to catch an additional disease, and far too many patients left the hospital only for the graveyard. Mistrust of doctors is still not entirely dead: some old people declare that when their time comes they intend to die without the assistance of any doctor. When some people are urged to seek medical advice, they reply, "I have never been to a doctor in my life, and I don't intend to start now." Stupid statements like this show that the speaker has no idea whatever of the enormous advances made in medicine in the last hundred years.

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Health has always been closely connected with happiness. From the beginning, therefore, man must have made efforts, however feeble and ignorant, to seek its source. How to relieve pain how to cure sickness, how to treat

injuries, which plants to eat and which to avoid, all these must have been the objects of man's attention from the earliest times.

The early civilizations all had their wise men, part of whose stock of knowledge was skill in the treatment of illness. By the time of the Babylonian and the Egyptian empires, a great number of medical ideas had accumulated, some of them sound and some, according to our standards, extremely unsound. The Greeks, who were pioneers in many branches of learning, obtained much of their knowledge from earlier scientists. They improved on what they had learnt, and it was the Greeks who laid the foundations of modern medical science.

One of the most honoured names in medicine is that of Hippocrates, sometimes called the Father of Medicine. It was he who first applied scientific methods to the study of disease. He and his disciples patiently observed facts and patiently recorded their observations. From the effect, they tried to determine the cause. They did not believe in magic, or in the influence of the stars, or in the power of the gods; they believed in the constant sequence of cause and effect. This belief was nothing less than a new religion.

Hippocrates the Physician was born on the island of Cos about 460 B.C. On this island a school of medicine had long been established. A great amount of badly assorted medical knowledge was in existence. Hippocrates and his disciples introduced scientific methods into the medical school of the island and into the whole of the Greek world. The method of seeking the cause after observing the effect is still called the Hippocratic method; another name is the inductive method. To us it seems a simple and natural way of working; but to people whose lives were governed by a belief in magic, in the influence of the heavenly bodies

and in the power of numerous gods, the new method was a revolution.

In spite of the great influence of Hippocrates on medicine, we know little about him personally. He is said to have been "learned, observant, humane, sympathetic with his patients, desirous that his experience and knowledge should benefit others, orderly, thoughtful and calm, pure of his mind and master of his passions." He lived a wandering life, practising and teaching; his pupils included his own sons and sons-in-law. He himself was a good example of the value of his teaching, for he lived to be a hundred years old. Before his time a certain illness had been called "the divine disease"[1] because it was thought to be caused by the ill will of the gods. Hippocrates opposed this idea, declaring that it must be due to ordinary causes, like other diseases. "As for this disease, called divine, surely it has its nature and causes like other diseases. It arises, like them, from things which enter and leave the body. . . . Such diseases have their antecedent causes which can be discovered by those who seek them."

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When the first great university of the world, the Museum of Alexandria, was established, medical science became an important study. There were two chief branches of this study, anatomy and physiology. The earliest important teacher of the medical school was Herophilus, who was a contemporary of Euclid. It is interesting to remember that the practice of dissecting the human body for the instruction of pupils, still a common part of medical teaching, was started in Alexandria more than two thousand years ago. Herophilus compared man's anatomy to that of animals. Paying special attention to the brain, he recognized that it

[1] Epilepsy.

was not only the centre of the nervous system but also the seat of the intelligence. This was a remarkable discovery; for most people of that time thought that the *heart* was the seat of the intelligence, and they continued to think so for long afterwards. This idea has left its mark on our language; we still talk of learning things "by heart"; we still say, "I took his words to heart"; and we still have "a heart to heart talk" with a friend. There are other expressions in English where the heart is used as the seat of understanding, feeling or thought.

Another distinguished professor of Alexandria was Erasistratus who specialized in the study of the brain and the nervous system. He showed that certain nerves carried messages *to* the brain (the sensory nerves) while others (the motor nerves) carried messages *from* the brain to the muscles. This discovery seems to have been either forgotten or neglected until it was rediscovered in the nineteenth century by Sir Charles Bell.

Both Herophilus and Erasistratus are accused of the terrible crime of dissecting the bodies of living men. Some historians have examined this charge and are convinced of its falsity. But both scientists, in the passion for scientific discovery, might not have hesitated to use the living body for their experiments. Life was cheap, and criminals sentenced to death might well have been placed at the disposal of the medical school. Valuable knowledge, of benefit to the whole race, might have been obtained by an experiment on a living, rather than on a dead, body. A scientist might not consider the accusation a very terrible one.

With the fall of the Greek empire, systematic experiments and regular medical study seem to have come to an end. Besides noticing what the Greeks discovered, we ought to see where their ideas were quite wrong. They

discovered much, and their knowledge formed the basis on which other medical knowledge was built when regular investigation was resumed after the Revival of Learning. But their wrong ideas were an obstacle in the way of progress when scientific study was begun again.

Erasistratus supposed that air was taken in by the lungs and then passed to the heart. Here, the air passed into the blood and was changed into a peculiar kind of "spirit" which was carried by the arteries to all parts of the body. This spirit was called the "vital spirit." When it reached the brain, it was changed into another kind of spirit, the "animal spirit." This animal spirit reached all parts of the body through the nerves, which he wrongly thought were hollow.

It is fairly easy to see why the ancients believed in this vital spirit, which began as air and was changed into something else by blood. The essential difference between a living and a dead body was that the former breathed and the latter did not. Knowing this, they naturally thought that breath, or what breath became, was life. Man consisted of two parts, body and vital spirit; when a man died, his "spirit" left the body and joined the world of spirit which was thought to be above the seventh heaven.

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Galen, another great figure in medical science, lived several hundred years after Erasistratus. Though he was great and famous, he had some mistaken ideas like those of his predecessors. According to him, when a man breathed, he drew in some world-spirit which entered his lungs and then his heart. Galen also believed that the nerves were hollow. He had little knowledge of the work of the heart. Nevertheless, his ideas concerning anatomy and physiology were put into a number of books, and

were the basis of medical knowledge until the sixteenth century.

What is the secret of the long life of some of these ideas? The answer is that they fitted in well with all the religious ideas of the time. Galen's works were translated into Latin, Syriac, Arabic and Hebrew and were studied for more than a thousand years. Learned men ceased to watch effects and determine their causes. They devoted themselves to the study of God's will. Theology became the queen of learning and remained so till the time of the Renaissance. The real work of the heart, and the circulation of the blood, remained undiscovered until the seventeenth century when William Harvey, in discovering them, laid the foundation of the modern science of physiology.

It was in 1628 that Harvey published his discovery together with a proof of its truth. He showed that the heart has a capacity of only two ounces. Every time it beats, it throws out two ounces of blood. As a normal heart beats 72 times a minute, it throws out $2 \times 72 \times 60 = 8{,}640$ ounces $= 540$ pounds in an hour. This is three times the weight of an average man. How can the heart pump out this enormous quantity of blood? It must be the same blood going and coming, leaving the heart and returning to it. This knowledge that the blood of animals is always circulating opened the door to investigation. It led to a great advance in the study of the working of living bodies, which is called physiology. Why does the blood circulate? What does it carry? Where does it pick up its load, and where put it down? To answer these questions has been one of the tasks of investigators since the time of Harvey.

* * * * * * *

At about this time observers looking at blood through the microscope noticed that it seemed to be composed of

little red bodies: they discovered the corpuscles of the blood. Later the microscope led to the discovery of germs or microbes. When the relation of germs to disease was discovered, a definite step forward was taken by medical science. We have not yet discovered the roots of all diseases, for some of the things that cause them appear to be so small that they cannot be seen through the microscope; yet this instrument has been of enormous value to medical research, and without it the causes of malaria and of yellow fever would not have been found.

The method by which microbes increase is interesting. An observer was once watching through his microscope a number of them swimming about in some liquid. He noticed that one was swimming up a little channel into a pool. Taking a tiny brush, he swept away the channel and thus imprisoned the single microbe in the pool. As he observed it, he saw its ends grow thicker and its middle grow thinner; he watched this continue until finally the microbe divided itself into two parts: there were now two instead of one. This method of reproduction in living creatures had never been known before. It explained how microbes were able to increase very rapidly and cause death.

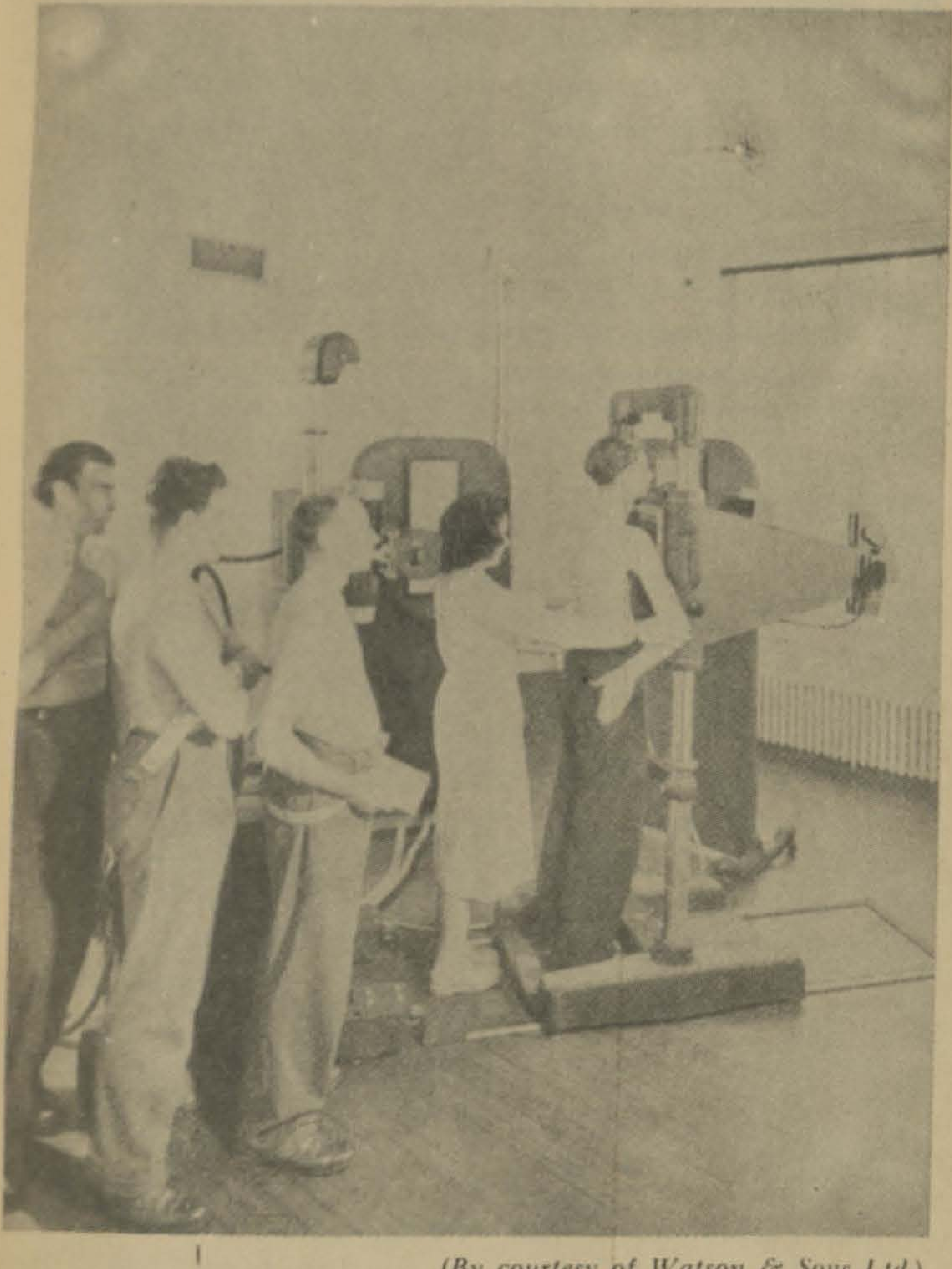
* * * * * * *

Of all the discoveries of medical science, few have benefited man so directly as that of the anæsthetic. The first anæsthetics were gases, ether and chloroform. No longer is it necessary to suffer the terrible pain of an operation, or to be knocked senseless before it takes place. A few breaths of gas, and one falls into unconsciousness, awaking to find the operation over. Other anæsthetics besides gases are now available: a drug may be injected into the body of the patient with a needle, and he immediately becomes uncon-

scious. In some cases he is able to get up and walk about the next day, for the after-effects of the anæsthetic are slight.

Another discovery of vast importance to medicine was made by Röntgen, professor of physics in the University of Wurzberg in 1895. The discovery was made partly by accident while the professor was experimenting with a cathode-ray tube. This is a glass tube from which the air has been almost completely removed. When an electric current at a high voltage is passed through the vacuum rays are emitted from the negative terminal called the cathode. Thus the rays are called cathode rays. (It is this kind of tube that shows the picture in a modern television receiver.) While Röntgen was carrying out his experiments, he covered the tube with a box made of black paper. Now black paper will not allow cathode rays to pass through it, yet he found that some other rays must be coming through it; for a screen covered with some barium salts which happened to be near his apparatus began to glow. He tried what would happen if he put things between the tube and the screen, and discovered that the rays would pass through a book of a thousand pages, a piece of wood, and even thin sheets of metal. When he interposed his hand, he was able to see the bones inside. As he did not know what kind of rays these were, he called them X-rays, the name which they still retain. The importance of this discovery was immediately understood, for it enabled doctors to see inside the living body without damaging it, and to take photographs of the positions of such things as broken bones in the foot, and swallowed coins in the stomach. X-rays are used every day in all parts of the world at the present time; the X-ray department of a modern hospital is a very busy place indeed.

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(By courtesy of Watson & Sons Ltd.)

Radiography for the detection of tuberculosis in its early stages

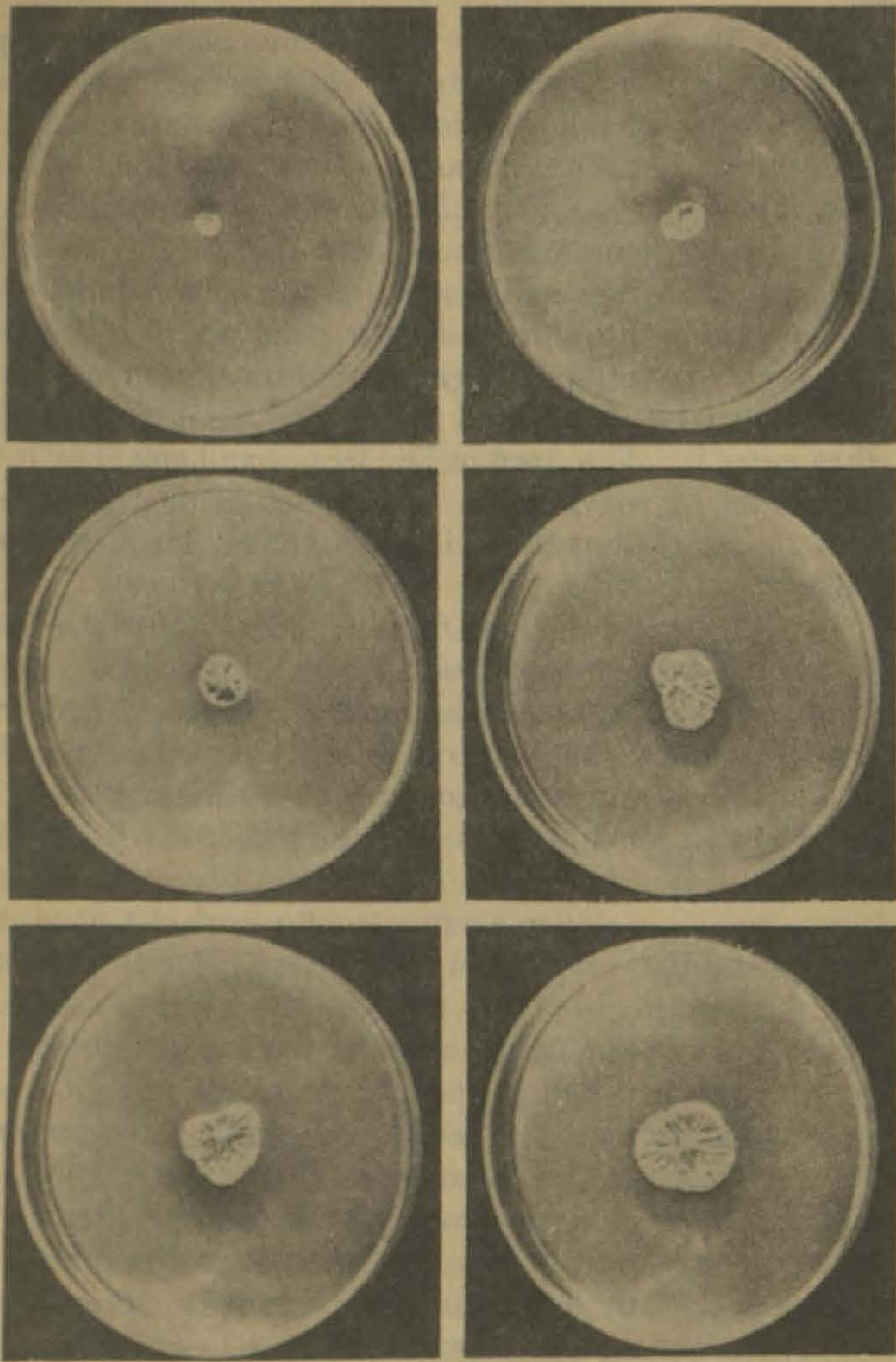
Recent years have added to the doctor's weapons in his fight against disease. In 1938 the British firm of manufacturing chemists, May and Baker, first prepared a drug which was given the number 693. It proved to be very successful against pneumonia and similar infections, and has become famous as "M & B 693." This was the drug used to cure Mr. Winston Churchill when he fell ill during the last war. It, and others like it, are now widely used to deal with certain infections and poisons in the body.

The world-famous drug penicillin was first discovered by Professor Alexander Fleming in 1929; but it was not until 1940 that Professor Florey at Oxford obtained successful results with it. The wonderful cures that penicillin has brought about have made some people think that it will cure nearly everything. This is quite wrong. The diseases to which mankind is subject are so many and so varied that obviously no single drug or treatment can cure them all.

More recently still, a new drug called streptomycin has been found useful in the treatment of some cases of tuberculosis. Anything that will help in the fight against this terrible and widespread disease is a blessing to the human race. There is apparently some doubt concerning the value of streptomycin, and doctors do not claim that it always cures tuberculosis: far from it. Yet the British Medical Association now allows it to be used.

* * * * * * *

Our hopes of getting better when we fall ill are now undoubtedly higher than those of our forefathers. But how much more satisfactory it is not to fall ill at all! Prevention is better than cure. To safeguard us against certain illness, doctors now rely upon inoculation and vaccination. "Oculus" is a Latin word meaning "eye": the word *eye* is used for the round mark on a potato from



(By courtesy of Glaxo Laboratories Ltd.)

Day-to-day stages in the growth of penicillin mould

which a little branch will grow. To inoculate means to put into the body something from which something else will grow. It has been known for a long time, since the time of Dr. Jenner, that if the germs of a disease in a mild form are introduced into the body, the blood builds up resistance to that kind of germ; and when, later, the body is exposed to that infection, it can usually resist it successfully. The doctor injects into our bodies the dead germs of a disease like typhoid; the body begins to fight against these germs and soon is well prepared to attack typhoid germs when they enter it. The story of Dr. Jenner and smallpox is the beginning of the practice of inoculation against disease; though, for reasons that will appear later, his method was called vaccination.

Looking round at your friends' faces, you will see few, if any, that are covered with small round pits. Yet two hundred years ago, a great number of people had their faces disfigured in this way. They were those who had had smallpox and had recovered. This dread disease left its marks on its victims, marks which they carried to their graves. Edward Jenner, wanting to become a doctor, apprenticed himself to a surgeon who worked a good deal among country people. In 1768, Jenner, not yet a doctor, heard a dairy-maid say that though there were many cases of smallpox in the neighbourhood she was not frightened because she had had cowpox. Jenner was interested and began to make inquiries; for learned people may sometimes learn a great deal by listening to ignorant ones. No one minded having cowpox, which was a mild disease, but smallpox was dreaded by all. Other doctors had heard of the idea that those who had had cowpox never caught smallpox, but they thought that it was an ignorant superstition, and they took no notice. It was some years before Jenner took any definite action to test the truth of the idea.

but he did not forget it. In 1796 he decided to give cowpox to a person and see if it was any protection against the other more dangerous illness. He inoculated a small boy with matter taken from the hand of a dairy-maid who had cowpox. A fortnight later, when he thought that the boy's blood would have strengthened itself against diseases of this kind, he inoculated the boy with smallpox. This was a brave but dangerous thing to do. What would have happened if the boy had caught smallpox and died? But Jenner was confident, and his confidence was justified: the boy did not develop smallpox. A second similar experiment was equally successful.

Many doctors flatly refused to believe Jenner when he announced that he had found a preventive against smallpox. They declared vaccination a dangerous practice. But the dread of smallpox was in everybody's heart, and people flocked to Jenner to be vaccinated. The Latin word for cow is "vacca"; it is the root from which the word vaccinate was formed. Some of the "vaccine" used by Jenner was not pure and some harm was done; but when supplies of pure vaccine were available, the practice of vaccinating spread all over England and from England to other countries. We rarely hear of outbreaks of smallpox now, for most parents have their children vaccinated at a very early age.

Several other diseases such as typhoid, which used to kill people in thousands, are now much less dangerous; and if people were more careful about being inoculated every two years, typhoid might die out. It is true that a few people get typhoid even when they have been inoculated; but they usually get a mild form of the disease and soon recover. Yet there are still some diseases that defeat the best doctors. One of these is infantile paralysis, the disease that President Roosevelt caught but so bravely fought. It

is showing signs of increasing. No one knows how it is spread; its germ has not yet been identified. Other diseases, too, have not yet been conquered; there is still plenty of scope in the field of medicine for the wisest brains and the bravest hearts.

* * * * * * *

The old dread of surgical operations has now largely passed away, for the great majority of them are successful. No modern surgeon would dream of performing an operation with instruments that had not been sterilized, that is, made surgically clean by steam-heat. Microbes no longer enter the wound that the surgeon makes: they are not allowed to come near it. The wound, therefore, has every chance of healing satisfactorily, and usually does so. In addition, the science of surgery has progressed to an astonishing degree. Some surgeons have even performed successful operations on the human heart. A new kind of operation on the brain is being performed for the relief of certain forms of madness. Blindness, too, can be cured in some cases. Some people are blind because the cornea, the outer covering of the eye, is not transparent. It was thought that if part of such a cornea was removed, and a portion of the cornea of a newly-dead person was stitched on in its place, the patient might recover his sight. This, as one may imagine, is a most delicate operation. Dillinger, an American gangster, who before his execution repented of his crimes, agreed that his eyes might be used to help medical science. When he was dead, his eyes were removed and rushed to a hospital where a patient was waiting. The cornea of the dead criminal was sewn on the eyeball of the patient, and grew there successfully. The ex-patient was soon walking about no longer blind, but seeing through the cornea that once belonged to Dillinger. This operation

has been repeated since. It is not a common operation, partly because it is difficult, and partly because there is not a plentiful supply of fresh eyes.

Never before in the history of the world has man known so much about his own body and the illnesses that attack it. Yet there are still difficulties to be overcome, curtains to be lifted, victories to be won. Many brave men have given their lives so that we may live. They have willingly inoculated themselves with germs, have exposed themselves to dangerous rays, have tested new anæsthetics on their own bodies, have sacrificed themselves to win some of the victories of peace. Others, following in their footsteps, will face new dangers and win new battles, and their names will be written on the roll of fame. Yet it is not only the famous men whom we honour. Every doctor in every part of the world, going about his daily work, fighting disease, bringing encouragement and hope to the sick, often turning sorrow into happiness, deserves our respect. There is no nobler calling than that of the doctor, the friend of man.

CHAPTER X

The Future

WE have read in this book of some of the great changes that have taken place very recently in the history of the world. If wars do not entirely destroy our civilization, it is probable that the changes that will occur in the next few centuries will be far greater than these. In what kind of world will our descendants live?

Our present cities are growing every year. They are like magnets, attracting people to them from the villages and the fields by their greater opportunities for work and pleasure. This growth will almost certainly continue, and the cities of the future will be much bigger and far more complicated than those of to-day. Many problems will arise which will have to be solved. The solutions will undoubtedly change the face of the city and the life of its inhabitants.

Some of these problems already face us. One of the most urgent is how to deal with the increasing amount of traffic in the streets. The streets are overcrowded now. What will happen when the amount of traffic is ten, twenty, fifty times greater?

It is quite possible that the future city will have no traffic at all. H. G. Wells, in his book *The Sleeper Awakes*, tells of a man who slept for hundreds of years, and awoke to a very different world from that which he knew before. In the streets of that future London there were no animals, carriages, motor-cars or tramcars. The city was provided

with moving roads, and therefore no longer needed the vehicles to which we are accustomed. One side of the road travelled in one direction; the other side moved the opposite way. Anyone who wanted to go to another part of the city stepped on the moving "way" and sat on one of the seats until he arrived. He did not need to wait for a tramcar or a bus; he had none of the troubles which a private car brings with it: whether there is enough petrol, whether the tyres are correctly inflated, where to park it. The moving way was always at his service, always moving silently along, always ready to take him to his destination. That city of the future had no traffic problems.

To link the various cities one with another, vehicles driven by atomic power will pass over non-skid roads surfaced with some new durable and elastic substance. These interurban highways will be divided into two main groups of lanes, one group for traffic in each direction. Each group will consist of several lanes allotted to vehicles travelling at different speeds, some for slow traffic, some for fast. Cross-roads will not exist on these highways, but will be replaced by bridges and curved junctions. Where these highways approach and enter cities, ports and other built-up areas, they will pass through underground tunnels.

It is fairly safe to prophesy that the power required to drive the machines of the future will be chiefly atomic power. The coal and the oil of the world will have been exhausted, and the power of the winds and the tides will be ignored in favour of the more convenient power obtainable from the splitting of the atom. Since the first test atomic bomb was exploded in New Mexico, and the two atomic bombs were dropped on Hiroshima and Nagasaki in Japan, the world has learnt that the atom can be split and its power used. The method of its use is a well-kept secret at the present time, but will be common knowledge

to future generations. The balanced forces which bind the electrons and protons of uranium and other atoms together will be released to serve mankind. In consequence of the unlimited power available to do the world's work, the citizens of the future will have a higher standard of living and a greater amount of leisure than we have now. The human energy thus released from the dull necessity of earning enough to live on will be applied to the greater enjoyment of life and the more complete conquest of nature.

* * * * * * *

In the simple-designed houses and flats of the future there will be many labour-saving devices. What a lot of time and energy is spent every day in cleaning our present houses! In the future we may be sure that the walls and the floors will not meet at an angle, but in a gentle curve which will prevent the accumulation of dust and dirt. There will be suction pipes fixed in the walls or ceilings to suck out all the accumulated dirt on the turning of a switch. Such things as central heating, air conditioning and indirect lighting will be normal; high-pressure cookers will prepare the daily meals in a few minutes, and electric washing-up machines will remove a great deal of the present toil in the kitchen.

There will, in any case, be fewer meals to prepare at home. It is probable that a person who for any reason finds it inconvenient to take a meal will merely swallow a tablet containing vitamins and other substances. Vast restaurants will provide meals of new and delicious foods. An endless band carrying the various dishes will pass before each visitor, and he will help himself to those that he chooses as they pass before him.

There will be a greater knowledge and appreciation of literature, painting and music, for people will have more

time for their enjoyment. The cinema and the theatre will no doubt be replaced, to a considerable extent, by a form of home gramophone-cinema. A man who wishes to spend a pleasant hour will fix a cylinder in his machine, sit in his armchair, and hear and see the play at home. His radio and television receiver will enable him to hear and see great orchestras, or to see events happening in distant countries while he sits in comfort.

Though everyone will be a member of the world telephone service and will be able to speak to a friend anywhere, on land, on the sea or in the air, there will remain a need for a postal system. It is probable that documents, books and so on will still have to be sent from place to place. All mail will be sent by air and, if the distance is great, by rockets travelling faster than sound. Many of these will pass over the North and South Poles, taking the shortest way to their destinations. Delivery will be quick. If a man in South America sends a letter to a man in China and it takes more than twenty-four hours on its journey, the world post-office will probably receive a very strong complaint!

Over long distances all passenger traffic and much goods traffic will be airborne. The aircraft of the future will doubtless be larger than ours and probably very different in construction. They will be driven at great speed by atomic power. A necessary part of every city and town will be its airport, which will be in a convenient position and connected to the various quarters of the town by moving ways.

The increasing amount of air traffic will direct attention to the control of the weather. Bad weather in our present world is responsible for accidents of various kinds, and in other ways is one of man's enemies. Rainstorms and floods cause damage, injury and death every year. The

heat of the tropics, and the freezing cold in the far north and south, cause discomfort and illness. Those who live in countries bounded by deserts suffer the horrors of burning sandstorms. The dangers of sea and air travel arise chiefly from storms, mist and fog. Rain, hail and snow interfere with the work and pleasure of the ordinary man. The farmer is never satisfied with the weather; if drought does not kill his crops, they are ruined by torrential rains and floods. Men will not suffer these annoyances for ever; they will study, and eventually control, the weather. The people of the future will live in a more orderly world, and life in those parts of the earth which now are desert areas will be as comfortable and pleasant as life in Switzerland. Atomic power will cool the tropics and heat the Arctic regions, and the North and South Poles will be inhabited by happy and prosperous citizens of the world.

The recent rapid progress in medical science promises well for the future. Medicine will stride forward to greater and greater triumphs. The energies and the wealth of the world will be directed, in large measure, to the cure and prevention of disease. We may be sure that the new methods of treatment introduced by drugs like penicillin are but the forerunners of more remarkable cures. Electricity will, no doubt, be brought into greater use in the fight against disease, and perhaps the power of the atom may be used to make people well and strong instead of to kill them. We may feel confident that the men, women and children of the future will be strangers to many of the illnesses which are prevalent at the present time.

* * * * * * *

All future progress, however, depends upon the abolition of war. War eats up the wealth and energy of men. It destroys man and the products of his skill and labour.

Some of the most promising scientists of the world have been killed on the battlefield. What waste and folly! Each war is more destructive than the last, not only in its immediate, but in its more lasting, effects. If the world cannot abolish war, the fate of civilization is obvious: it will go down in gigantic ruin. The only solution appears to lie in the formation of one world government, which will punish wicked nations as a government now punishes wicked men. If that can be done, and if the vast activity of man is used for construction instead of destruction, there is no limit to the possible progress of the human race. Tennyson, an English poet writing in the nineteenth century, looked into the future and saw the destiny of man, which was to labour and to fight

Till the war-drum throbbed no longer, and the battle-flags
were furled,
In the Parliament of man, the Federation of the world.

Let us hope that he was right.

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GLOSSARY

ABANDON: leave; give up.
ABILITIES: cleverness; what one is able to do.
ABOLISH: put an end to.
ABOLITION: noun of "abolish."
ABSENT ONESELF: be absent.
ACCENT: a mark on a letter, like é.
ACCOMPANY: go with.
ACCOUNT FOR: explain.
ACCUMULATE: collect.
ACCUMULATION: collection.
ACCURATE: exact.
ACHIEVE: reach; get.
ACHIEVEMENT: successful effort.
ADDITIONAL: extra.
ADVANCEMENT: progress.
ADVENTUROUS: loving adventure; full of adventure.
AERIAL: wire put up in the air to collect radio signals.
AERODROME: place where aeroplanes start and come down.
AFFECT: have an influence on.
AFTER-EFFECTS: results which come afterwards.
AID: help.
AIR-CONDITIONING: the action of making air pure and of the right temperature.
AIRCRAFT: aeroplane or aeroplanes.
AIRMAN: the man who directs an aeroplane.
AIRPORT: place where aeroplanes start and come down.
ALARM: frighten.
ALLOT: give (a part) to.
ALPHABET: all the letters, a, b, c, etc.
AMAZE: astonish.
AMID: in the middle of.
AMPLE: enough.
AMPUTATE: cut off (a limb) with medical skill.
ANÆSTHETIC: something to make a person unconscious during operations.
ANATOMY: knowledge of the way in which the body is built.
ANCESTOR: one from whom a person is descended.
ANCIENTS (the): the men of the past.
ANNOUNCE: declare.
ANTECEDENT: going before; earlier.
ANTHRACITE: a kind of coal that burns with little smoke.
ANTIQUITY: the times of long ago.
APPARATUS: instruments; machines.

APPARENT: clear.
APPARENTLY: it seems that.
APPLICATION: use; the use of something for some purpose.
APPLY TO: use for. Apply brakes: make them press on the wheels.
APPRECIATION: enjoyment, together with a realization of the good qualities.
APPRENTICE ONESELF TO: help and work with in order to learn.
APPROACH (verb): go near.
APPROACH (noun): the action of going near.
ARCTIC: the cold place in the north of the earth.
AREA: part of the surface of the earth.
ARMCHAIR: a chair with places to rest arms.
ARTERY: tube carrying blood from the heart.
AS REGARDS: concerning.
ASCENT: the action of going up.
ASPHALT: a hard black substance used in making roads.
ASSEMBLE: bring together; put together.
ASSEMBLY: meeting.
ASSEMBLY LINE: the line where manufactured goods are put together
ASSISTANCE: help.
ASSISTANT: helper.
ASSORTED: mixed up.
ASTRONOMER: scientist who studies the stars.
ASTRONOMICAL: adjective of "astronomy."
ASTRONOMY: the science of the study of the stars.
ASYLUM: safe building for mad people or poor people.
AT ANY RATE: in any case.
AT CLOSE QUARTERS: near.
ATMOSPHERE: the air round the earth.
ATMOSPHERIC: connected with the atmosphere.
ATOM: small part of matter that can be divided only into electricity.
ATOMIC: adjective of "atom."
ATTACH: fasten to.
AUTOMATIC: which works without the help of men.
AUTOMATICALLY: without the help of men.
AVAILABLE: ready for use.
AWAIT: wait for.
AWAKE: wake.
AWARE: knowing.
AWFUL: terrible.
AXIS: imaginary line round which anything turns.
AXLE: rod on which a wheel turns.

BALLOON: bag full of gas, for rising in the air.
BALLOONIST: man who goes up in a balloon.
BARBAROUS: not civilized.
BARIUM SALTS: the salts of a silver-like and heavy metal.
BATTERY: box which stores or produces electricity.
B.C.: before (the birth of) Christ.
BEACON: signal fire.
BENCH: workman's table.

BENEFACTOR: a man who does good.
BENEFIT (verb): do good to.
BENEFIT (noun): advantage; help.
BET: pay money in the hope of getting more if a certain event happens.
BILLION: million million; 1,000,000,000,000.
BINOCULARS: glasses for seeing over long distances with both eyes.
BIPLANE: aeroplane with two wings.
BLANKET: woollen bed cover.
BLEED: take blood from.
BLUBBER: the fat of the whale, which is the largest sea creature.
BOIL DOWN: make less in quantity by boiling.
BOILER: part of a steam-engine where the water is boiled to make steam.
BOLT: rod with a screw round it.
BOMB (noun): ball full of explosive material, to be dropped from aeroplanes.
BOMB (verb): to drop bombs on.
BOMBER: aeroplane that drops bombs.
BOY SCOUT: boy who learns to help others and to live in camp.
BRAKE: thing to stop the wheels of a train, motor-car, etc.
BRAND NEW: quite new.
BROADCAST: send out radio signals in all directions.
BRILLIANCE: brightness; cleverness.
BRILLIANT: bright, clever.
BRING ABOUT: cause.
BUILT-UP AREA: place where there are houses.
BUT: only.
BUT THEN: but, of course.
BUY OUT: buy the business from.
BY HEART: by memory.

CABLE: thick telegraph wire under the sea.
CALAMITY: terrible event.
CALLING: work to which a man feels called by God.
CAMBERED: having the centre higher than the edges.
CAPACITY: amount that can be contained.
CARBON: a black substance found in wood, coal, etc.
CARPET: covering for the floor.
CATHODE: the negative part of an electric tube.
CATHODE RAYS: rays that come from the cathode.
CEASE: stop.
CEILING: roof of a room.
CENTIGRADE: the scale for heat measurement in which boiling water shows 100.
CHANNEL: bed of a stream of water.
CHASSIS: frame of a car.
CHEMISTRY: the science which teaches how matter is made up.
CHEMIST'S (shop): shop where we buy medicines.
CHLOROFORM: a gas used to make people unconscious.
CHOP: cut into small pieces.
CIGARETTE: tube of paper containing tobacco.

CINEMA: theatre where moving pictures are shown.
CIRCLE: go round.
CIRCUIT: electric path.
CIRCULATE: go round.
CIRCULATION: noun of "circulate."
CIRCUMSTANCES: conditions.
CLIMATE: the weather conditions of a country.
CLUMSY: unskilful.
COACH: carriage.
COAL FACE: the place where the coal is cut from the earth.
COALMAN: the man who brings the coal.
COAL PIT: coal mine.
COASTAL: of the coast.
COCK: male bird.
COD: a fish.
CODE: system of signs which mean letters, or sentences.
COIL: wire in the form of a circle or circles.
COLLISION: the act of running into something.
COMMONPLACE: very ordinary matter.
COMMUNICATE: send news.
COMMUNICATION: the sending of news; the joining together.
COMPARABLE: which may be compared.
COMPEL: force; make.
COMPRESS: press together.
CONCLUSION: end; decision.
CONDENSE: turn steam into water by making it cold.
CONFIRM: prove to be true.
CONNECTING-ROD: the rod which joins the piston-rod to the wheel.
CONNECTIONS (family): relations.
CONSEQUENCE: result. In consequence of: as a result of.
CONSIDERABLE: rather great.
CONSIST OF: to be made of.
CONSTANT: not changing.
CONSTRUCT: build.
CONSTRUCTION: building.
CONSUMER GOODS: goods which are regularly used up.
CONSUMPTION: the act of using up, or of eating.
CONTEMPORARY: a person who lives at the same time.
CONTINENT: the largest division of land.
CONTINUALLY: very often.
CONTRARY: opposite.
CONTRIBUTE: give, together with other people, for a common purpose.
CONVEY: carry.
CONVEYOR BELT: belt which carries goods.
CONVINCE: persuade.
COOL: become cold; make cold.
CORD: thin rope.
CORNEA: front part of the eye.
CORPORATION: company.
CORPUSCLES: bodies in the blood.
COUNTLESS: which we cannot count; very many

COUNTRYSIDE: the open fields, not the town.
COUPLED WITH: joined with.
COWPOX: a disease of the cow.
CRAFTSMAN: skilful worker.
CRAFTSMANSHIP: skill in work.
CRANK: a bend in an axle (rod).
CREATE: make.
CRUDE: rough; not pure.
CRYSTAL: regular shape which some materials take when they become solid.
CYLINDER: a hollow case, in shape like a roller.

DAIRY: place where cows are milked.
DAM: to make a wall to keep back water.
DART: a pointed piece of paper thrown by the hand through the air.
DASH: a long mark —.
DEFINITE: fixed and clear.
DELICIOUS: having a very good taste.
DENY: say that it is not true.
DEPLORE: be sorry about.
DEPOSIT (noun): solid matter which sinks to the bottom of a liquid.
DEPOSIT (verb): to put down and leave.
DESCEND: go down.
DESIGN: plan.
DESIROUS: wishing.
DESTINATION: place to which one is going.
DESTINY: fate.
DETECT: find out.
DETECTOR: instrument which finds out if rays are present.
DEVICE: invention; instrument.
DEVOTE ONESELF TO: give one's life and work to.
DEW: water which appears on plants after sunset.
DIAMETER: straight line from one side of a circle to the other, through the centre.
DIESEL: engine driven by heavy oil.
DIFFER: be different from.
DISASTER: terrible event.
DISASTROUS: bringing disaster.
DISCIPLE: follower and pupil.
DISFIGURE: to make ugly.
DISPOSAL: control.
DISSECT: cut into parts in order to examine.
DISTRUST: not to trust.
DIVINE: of the gods; of God.
DOCUMENT: paper on which something important is written.
DONOR: giver.
DOUBTLESS: without doubt.
DRAG: go slowly.
DRAUGHT: current of air.
DRAWBACK: disadvantage.
DREAD (verb): fear greatly.

DREAD (noun): great fear.
DREAD (adjective): terrible.
DREADFUL: terrible.
DREAM OF: agree to.
DRILL (verb): make a hole.
DRILL (noun): tool for making holes.
DRILLER: man who works a drill.
DRIVING WHEELS: the wheels which move the engine.
DROUGHT: dryness; lack of rain.
DRUG: a medicine.
DURABLE: which lasts a long time.
DYNAMO: machine which produces electricity when turned.

ECONOMIC: adjective of "economy."
ECONOMICALLY: without waste.
ECONOMY: the science of the production of wealth.
EJECTION: throwing out.
ELDERLY: rather old.
ELECTRO-MAGNET: instrument that attracts iron when electricity flows through its wires.
ELECTROMAGNETIC: connected with electricity and magnetism.
ELECTRON: unit of negative (−) electricity.
ELEMENT: simple substance of which others are made.
ELLIPSE: flattened circle; what a circle looks like if you look at it sideways.
EMERGE: come out.
EMIT: send out.
ENABLE: make able.
ENERGY: strength and activity.
ENGAGED: busy.
ENGRAVE: cut pictures or names on metal or wood.
ENORMOUS: very great.
ENSURE: make sure.
ENTHUSIASTIC: eager and interested.
EPIDEMIC: disease which spreads quickly over a country.
EPILEPSY: disease which causes a man to fall down suddenly.
ESTABLISH: build up.
ESTIMATE: form an opinion.
ETHER: thing through which the waves of light are supposed to pass.
ETHER (gas): gas which makes a person unconscious.
EVEN SO: in spite of this.
EVENTUALLY: at last; in the end.
EVIDENTLY: clearly.
EXCEEDINGLY: very much; very.
EXECUTION: putting to death by law.
EXERTIONS: activity.
EXHAUST: use up; make tired.
EXHIBITION: public show.
EXPAND: become greater; make greater.
EX-PATIENT: one who was formerly a patient (see patient).
EXPERT: very skilful.

EXPORT: the sending of goods out of a country.
EXPOSE TO: lay bare; take away the protection.
EXTERIOR: outside.
EXTRACT: take out.
EXTRACTION: the taking out.
EYE-PIECE: the glass to which the eye is put when looking through an instrument.

FALSITY: falseness.
FEDERATION: union of many states.
FEEBLE: weak.
FETCH: go and bring.
FIRE-ENGINE: old name for steam-engine.
FIRM: company.
FISHERIES: work or place of catching fish.
FIT IN WITH: suit.
FLANGE: raised part at the edge.
FLATLY REFUSE: completely refuse.
FLATTERY: false praise.
FLEE: run away.
FLOCK TO: go in large numbers to.
FOG: thing like a cloud in the air which makes it hard to see far.
FOLLOW THE FORTUNES: watch the fortunes.
FOLLY: foolishness.
FOR: in relation to.
FORCIBLE: adjective of "force."
FOREFATHERS: those from whom we are descended.
FOREMOST: in the front.
FORERUNNER: thing which comes before.
FORETELL: tell before it happens.
FORETHOUGHT: power to see the future and prepare for it
FORMATION: the making.
FORTNIGHT: two weeks.
FOUND: to lay the base or basis of.
FOUNDATION: base; basis.
FRICTION: rubbing which causes heat.
FUEL: something to burn.
FULFIL: complete.
FUMES: smoke or gas from anything burning.
FUNDAMENTAL: chief; most necessary.
FUNNEL: chimney of a railway-engine or ship.
FURIOUSLY: fiercely.
FURL: roll up and use no more.
FURNACE: hot fire.

GALLERY: passage in a coal mine.
GANG: group of men.
GANGSTER: one of a group of criminals.
GASEOUS: adjective of "gas."
GAZE: look at for a long time.
GENERAL: army officer of very high rank.

GENERATION: all the people of one time.
GEOLOGIST: scientist who studies the surface of the earth.
GERM: very small living thing which causes disease.
GIANT: very big man.
GIGANTIC: very big.
GIN: machine for cleaning cotton.
GIVE BIRTH TO: bring to life; cause to arise.
GLANCE: short look.
GLIDE: move gently through the air.
GLIDER: machine which glides; aeroplane without an engine.
GLOW: shine.
GO TO MAKE: help to make.
GRADE: standard; quality.
GRAMOPHONE: instrument which produces music from records.
GRAVEYARD: place full of graves.
GRAVITATION: attraction of one mass for another.
GRAVITATIONAL: adjective of "gravitation."
GRAVITY: attraction of the earth.
GREAT-GRANDFATHER: father of grandfather.
GUSHER: place in the ground from which oil rushes out.

HAIL: ice which falls from the sky.
HALIBUT: a fish.
HANDIWORK: work of the hands.
HASTEN: cause to come quickly.
HEAD FOR: go towards.
HEART TO HEART: confidential; very friendly.
HEAVENLY: of the sky.
HEAVENS: sky.
HELIUM: gas first found on the sun.
HELP ONESELF TO FOOD: give oneself food.
HENCE: in the future.
HIGHWAY: important road.
HISTORIAN: man who writes history.
HOLD UP: stop.
HONOUR: give honour to.
HORIZON: place where the earth and sky seem to meet. New horizons: new ideas.
HORRIBLE: terrible; causing great dislike.
HORROR: fear and dislike.
HORSE-POWER: unit of measurement of force.
HOUSEHOLD: people of a house.
HOUSING: the providing of houses.
HOWEVER: but; in spite of that.
HUGE: very big.
HUMANE: kind.
HYDROGEN: a gas found in water.

IDENTIFY: recognize.
IGNORANCE: lack of knowledge.
IGNORANT: lacking knowledge.

IGNORE: take no notice of.
ILLUMINATE: give light to.
ILLUMINATION: the providing of light.
IMAGE: picture.
IMPASSABLE: which cannot be passed over.
IMPORT: to bring into a country from abroad.
IMPRISON: put in prison.
IN HIS RIGHT SENSES: not mad.
IN LARGE MEASURE: to a great extent.
IN THIS RESPECT: in connection with this point.
INCLINED: feeling a slight wish.
INCREDIBLE: which cannot be believed.
INDICATE: show.
INDICATOR: instrument which shows something.
INDIVIDUAL: connected with a single person.
INDIVIDUALITY: special quality; difference from others.
INDUCTIVE: way of reasoning from many known facts to one law.
INFANTILE: connected with babies.
INFECTION: poison which enters the body.
INFECTIOUS: poisonous and spreading.
INFLAMMABLE: which easily catches fire.
INFLATE: fill with air.
INFLUENCE: have an influence on.
INFREQUENT: not happening often.
INHABIT: live in.
INHABITANT: a person who lives in.
INJECT: put into the body with a needle.
INJURE: hurt.
INJURY: wound.
INOCULATION: the putting of dead germs into the body so that it may be able to resist a certain disease.
INSTANCE: example.
INSTRUCTION: teaching.
INSUFFICIENT: not enough.
INTELLIGENCE: power of the mind.
INTELLIGENT: clever.
INTERNAL: inside; inner.
INTERNAL COMBUSTION ENGINE: petrol engine which burns petrol inside.
INTERPOSE: put between.
INTERURBAN: between cities.
INTERVAL: time between two events.
INVALID: person in bad health.
INVERTED: turned over; turned upside down.
INVESTIGATION: inquiry.
INVESTIGATOR: man who inquires into something.

JET: stream of gas coming out of a small hole.
JET-PLANE: aeroplane driven by jets.
JOB: piece of work.

JUNCTION: joining.
JUSTIFY: prove to be right.

KEEN: sharp; active.
KETTLE: thing in which we boil water.
KILOMETRE: rather more than half a mile.
KITE: frame covered with cloth which children cause to fly in the air.
KNIT: join threads together to make cloth, etc.

LABORATORY: room where scientific experiments are made.
LABORIOUSLY: with much hard work.
LABOUR (verb and noun): work.
LABOURER: workman.
LACE (of shoe): narrow band of cloth or leather, used to pull the edges together.
LANE: part of road.
LAYER: thickness of matter spread over a surface.
LEISURE: time when there is no work to do.
LEISURELY: slow; having plenty of time.
LENGTHY: long.
LENS: curved piece of glass for bending light.
LEVER: bar which can be moved.
LIABLE TO: in such a state that it may.
LIFETIME: life.
LIGHTHOUSE: building which shows a light to guide ships.
LIGHT-YEAR: the distance which light travels in one year.
LINK: join.
LIVER: that part of the body which takes poisons out of the blood.
LOCOMOTIVE: travelling steam-engine.
LONG TO: wish very much to.
LOOM: machine for making cloth.
LORRY: large motor for carrying heavy goods.
LOT: fate.
LUBRICATE: put oil in, so that the machine will work smoothly without getting hot.
LUBRICATION: noun of "lubricate."
LUNATIC: mad person.

MAGIC: strange powers, such as those of spirits.
MAGNET: piece of iron or steel which attracts iron.
MAGNIFY: make greater.
MAID: girl or woman servant.
MAINTAIN: keep up; support.
MAJOR: greatest; very great.
MAJORITY: more than half; the greater number.
MAKE UP FOR: do something good to balance something bad which has been done.
MALARIA: a fever.
MANKIND: the race of men.
MARINE: of the sea.
MARTIAN: adjective of "Mars

MAST: high post on a ship to support sails or wires.
MATHEMATICIAN: a man who is clever at mathematics.
MATHEMATICS: the science of numbers.
MAXIMUM: the greatest number.
MEAGRE: not enough; little.
MECHANICS: the science of machines.
MENTAL: of the mind.
MERCURY: a heavy liquid metal.
METHOD: way of doing something.
MICROBE: small living thing which causes illness.
MICROSCOPE: instrument for examining very small things.
MIGHT WELL HAVE BEEN: were probably.
MILLIONAIRE: a man who owns a million pounds or dollars.
MINERAL: which comes out of the earth.
MINIMUM: the smallest number.
MINUTE: very small.
MIRROR: glass or metal which reflects light.
MISFORTUNE: unhappy event; bad luck.
MIST: something like a cloud which fills the air and makes it hard to see far.
MISTRUST: lack of trust.
MISUNDERSTAND: understand wrongly; get the wrong idea.
MOLTEN: melted; so hot that it is like a liquid.
MONOPLANE: aeroplane with one wing.
MONSTER: large and terrible creature or thing.
MOTOR NERVE: nerve which carries messages to the muscles. (See nerve, muscle.)
MOTTO: words which may act as a guide in life.
MULTIPLE MACHINE: machine that is several machines in one.
MUSCLE: part of the body which causes movement.
MUSEUM: building containing interesting things for people to see. The Museum of Alexandria was the name of the first university.
MUTTER: say quietly, to oneself.

NAKED EYE: the eye without the help of any instrument.
NARROW DOWN: reduce.
NATIONALIZATION: noun of " nationalize."
NATIONALIZE: put under the control of the nation.
NAVY: the warships of a nation.
NEBULA: mass of gas beyond the stars.
NEBULÆ: plural of nebula.
NEGATIVE: (−)
NERVE: thing like a thread in the body which carries messages to and from the brain.
NERVOUS: easily frightened.
NERVOUS SYSTEM: the system of nerves in the body.
NEVERTHELESS: in spite of that.
NEWCOMER: person who comes new to the work or place.
NIB: piece of metal put in the end of a penholder to write with.
NICKNAME: name used jokingly.
NO NEWS VALUE: useless as news.

NO WONDER: it is not surprising.
NOD: move the head up and down to show "Yes."
NON-SKID: which will prevent slipping.
NORMAL: ordinary.
NOTE: take notice of.
NOURISH: feed well; strengthen the body.
NOWADAYS: in these present days.
NUT: small piece of metal with a hole in the middle, to screw on to a rod.

OBSCURE: cover; make dark.
OBSERVANT: cleverly noticing things.
OBSERVER: person who watches.
OBSTACLE: something which prevents movement or action.
OBTAIN: get.
OBTAINABLE: which can be got.
OBVIOUS: very clear.
OBVIOUSLY: very clearly.
OCCUPATION: something on which we spend time.
OCCUR: happen; be used.
ONCE: when; as soon as.
OPERATOR: person who looks after a machine or instrument.
ORCHESTRA: band of good musicians.
ORDERLY: tidy.
ORIGINATE: start; begin.
OTHER THAN: except for.
OUT OF ACTION: not working; out of order.
OUTBREAK: a breaking out; a bursting out.
OUTPUT: what is produced; quantity produced.
OVERHEAD: above the head.
OVERSEAS: across the seas.
OWING TO: because of.
OXYGEN: a gas found in water and air.

PADDLE-WHEEL: wheel at the side of a ship to drive it through the water.
PARAFFIN OIL: oil which is used in lamps.
PARALYSIS: disease which prevents the movement of the body.
PARK: place the motor-car in a place where it may wait.
PARLIAMENT: group of men who represent the people of a country.
PARTIAL: not complete.
PARTNER: person who shares in work or play.
PASSION: great feeling of love, anger, hate, or eagerness.
PASTIME: something which will pass the time.
PATCH: piece of cloth put over a hole; anything that looks like this.
PATIENT: sick man in the care of a doctor.
PENICILLIN: a new cure for certain poisons of the body.
PERFECT: make perfect; improve very much.
PERFUME: scent.
PERIOD: length of time.
PERPETUAL: going on for ever.
PETROL: oil which drives a motor-car or aeroplane.

PETROLEUM: rock-oil; mineral oil.
PHRASE: group of words which do not form a sentence or clause.
PHYSICAL: adjective of "physics."
PHYSICIAN: doctor who gives medicine.
PHYSICS: the study of the natural world and its forces.
PHYSIOLOGY: the study of the way in which a living body works.
PIERCE: make a hole through. Pierce fog: show what is in front in the fog.
PILOT: man who flies an aeroplane.
PIONEER: first worker.
PIPELINE: long pipe to carry water or oil across the country.
PISTON: thing moved backwards and forwards by steam in a cylinder.
PISTON-ROD: rod fixed to the piston.
PIT: coal mine; shallow hole in the skin.
PITCH: black sticky substance which comes from coal.
PLANET: thing which goes round the sun, like the earth.
PLANETARY: adjective of "planet."
PLATELAYER: man who takes care of the lines of a railway.
PLATFORM: that part of a railway station on which people stand.
PLUNGE: put in suddenly.
PNEUMONIA: disease of the lungs like a very bad cold.
POCKET OF GAS: imprisoned gas.
POINTS OF RAILWAY: the place where two lines join together.
POLE: man from Poland.
POLES; the north and south parts of the world.
PONY; small horse.
PORT: commercial city near the sea.
PORTION; part.
POSTAL: of the post-office.
POTATO: a white root often eaten with meat.
POTTERY: pots made of clay.
PRACTICALLY: almost.
PRACTISE: work as a doctor.
PRECAUTIONS: care taken to prevent accidents.
PREDECESSOR: man who did the same work before.
PRESCRIBE: order as treatment.
PRESENT: offer.
PRESENT AT COURT: introduce to the king.
PREVALENT: common.
PREVENTIVE: something which prevents a disease.
PREVIOUSLY: before; earlier.
PRINCIPLE: general law or rule.
PRISM: piece of glass for breaking up the rays of light.
PROCESS: way of working.
PROCURE: get.
PROFESSOR: highest teacher of a subject in a university.
PROFOUNDLY: deeply.
PROMISING SCIENTIST: one who will probably be a great scientist.
PROPHESY: tell the future.
PROSPECT: search a place, to try to find (oil).
PROSPER: do well; succeed; become rich.

PROSPERITY: success; the state of being rich.
PROSPEROUS: successful and rich.
PROTON: bit of positive electricity found in the centre of an atom.
PROVERB: old saying.
PROVISION: the providing; supply.
PUBLISH: make public; give to the public in newspapers or books.
PUNCTUATION: the stops used in writing such as . , ; : ?
PURCHASE: buy.
PURCHASER: one who buys.

QUARTERS OF A TOWN: the different parts of a town.
QUEER: strange.

RACE THE ENGINES: make them turn very fast.
RACK-RAIL: a rail with teeth between the other two.
RADAR: way of finding unseen objects by means of short radio waves.
RADIATE: send out rays; send out in rays.
RADIATION: the sending out of rays.
RADIATOR: anything which sends out rays, especially rays of heat.
RADIOLOCATION: radar.
RARITY: rare thing.
REAR: back.
REASONABLE: not too great; sensible.
REBUILD: build again.
RECOVER: get better; get back again.
RECOVERY: reaching the better state it was in before.
REDISCOVER: discover again.
REFINE: make pure.
REFINERY: works where oil is made pure.
REFRACT: bend (light).
REFRACTOR: telescope or other instrument which bends light; which uses a lens.
REGION: place; part of the country.
RELAY: instrument which receives weak signals and sends on strong ones.
RELEASE: set free.
RELY: depend.
REMARKABLE: above the average.
RENAISSANCE: the rise of learning again.
RENDER POSSIBLE: make possible.
REORGANIZATION: better arrangement.
REPENT: be sorry for having done wrong.
REQUIRE: need.
RESEARCH: the search for knowledge.
RESERVOIR: artificial lake.
RESTART: start again.
RESTORE: bring back.
RESTRICTION: rule which limits.
RESUME: begin again.
RETAIN: keep.

REVENUE: money which a government gets.
REVIVAL: the rising again.
REVIVE: bring to life again; cause to rise again.
REVOLUTION: great change.
REVOLUTIONIZE: change completely.
REVOLVE: go round.
ROCKET: thing that flies through the air driven by gas sent out backwards.
ROLL OF FAME: list of famous people.
ROTATE: turn.
ROTATION: turning.
ROUGH AND READY: rough and convenient, but not very suitable.
ROYALTY: money paid to the owner of the land producing oil.
RUN SHORT OF: come to the end of; not to have enough.

SAFEGUARD: protect.
SAFETY-VALVE: thing which lets steam out of a boiler when the pressure is high.
SALAD: green leaves used as food but not cooked.
SCOPE: opportunity for action and work.
SEAM: layer of coal.
SEASIDE: place by the sea where people go to enjoy themselves.
SECTION: part.
SEDIMENTARY ROCK: rock made by the falling of bits of material to the bottom of the sea.
SEEK: try to find.
SEMAPHORE: wooden or metal thing with arms for sending messages.
SEMI-: half-.
SEND WORD: send a message.
SENSORY NERVE: nerve which carries messages to the brain.
SENTENCE (verb): to give judgment on (a person).
SEQUENCE: the following of one thing after another.
SERVE A PURPOSE: be useful for a purpose.
SET ONE THINKING: make one think.
SHALE: a kind of rock.
SHIP (verb): send by ship.
SHIVER: shake with cold.
SHORTAGE: lack; the state of not being enough.
SIGNAL-BOX: building where a man works the railway signals.
SILVER-WARE: goods made of silver.
SIMILAR: like; not different.
SINCE: because.
SIREN: whistle of a ship.
SLOW DOWN: begin to go slowly.
SMALLPOX: a disease which covers the skin with spots.
SO FAR: until then; until now.
SOUND (adjective): healthy; correct.
SOURCE: origin.
SPANNER: key for turning nuts.
SPARK: sudden flash.
SPECIALIZE IN: do (one kind of work) especially, and not others.

SPECTACLE-MAKER: man who makes glasses for the eyes.
SPECTROSCOPE: instrument for examining light.
SPECTRUM: band of coloured lights produced by the spectroscope.
SPEEDY: quick.
SPHERE: ball.
STABILITY: steadiness.
STANDING: position.
STANDSTILL: stop.
STARTLE: surprise very much.
STARVATION: dying of hunger.
STATIONARY: not moving.
STERILIZE: make perfectly clean by boiling or using steam.
STITCH: sew.
STOPPAGE: stopping.
STREPTOMYCIN: something which may cure tuberculosis in some cases.
STRICKEN: struck.
STRIDE: go with long steps; go quickly.
STRIKE OIL: find oil.
STRIP OFF: take off in strips.
STRUCTURE: building.
STUDIO: room where artists and musicians work.
STUMP: the part not cut off.
SUBJECT TO: likely to catch.
SUCTION PIPE: a pipe for sucking.
SUFFICIENT: enough.
SULPHUR: yellow substance which burns with a bad smell.
SUMMON: call.
SUN-SPOT: spot on the surface of the sun.
SUPERIOR: better; of better quality.
SUPERSTITION: foolish belief.
SUPPOSITION: a thing which is supposed.
SUPREME: better than all others.
SURFACED WITH: covered with.
SURGEON: doctor who does operations.
SURGERY: the science of operations.
SURPLUS: what is left when what is needed has been taken.
SWAN: beautiful bird with a long neck, which lives on the water.
SWITCH: instrument for joining electric wires or breaking the connection.

TABLET: small thing to swallow.
TAKE DELIVERY: receive from the shop or maker.
TAKE OFF: leave the ground.
TAKE STEPS TO: do something in order to.
TAKE TO HEART: consider seriously.
TANK: fighting machine which moves.
TAR: black sticky substance which comes from coal.
TARGET: the thing that one aims at.
TELESCOPE: instrument for seeing long distances.
TELEVISION: science of sending moving pictures by radio.

TEMPORARILY: for a time.
TEND: look after.
TERMINAL: end of an electric wire.
TERRIFY: frighten very much.
TERROR: great fear.
THEOLOGY: science of religion.
THEORY: general idea which will explain a number of facts.
THROB: beat strongly.
THROUGHOUT: through all of.
TINY: very small.
TIRELESS: never stopping; always continuing.
TOIL: hard work.
TORRENTIAL: falling in great quantities.
TORTOISE: animal with a hard covering from which the head, legs and tail come out.
TRACE: small sign.
TRAFFIC: motor-cars, carriages and so on, in a street.
TRAMCAR: street carriage driven by electricity.
TRANSATLANTIC: which crosses the Atlantic ocean.
TRANSFUSION: the putting of another person's blood into a living body.
TRANSMITTER: radio sending station or instrument.
TRANSPARENT: which can be seen through.
TRANSPORT (verb): carry.
TRANSPORT (noun): the carrying of goods; the things which carry goods.
TREATY: signed agreement between two countries.
TREMENDOUS: very great.
TRIANGULAR: having three angles.
TRIPLANE: aeroplane with three wings.
TRIUMPH: victory.
TROPICS: the hot parts of the world.
TUBERCULOSIS: terrible disease, particularly of the lungs.
TUNNEL: horizontal hole through the earth.
TYPE: kind; sort.
TYPHOID: a fever.
TYRE: rubber covering of a wheel.

UNAWARE: not knowing.
UNCONTROLLABLE: which cannot be controlled.
UNDER CONSTRUCTION: being built.
UNDERFED: not fed enough; without enough food.
UNDERTAKE: decide to do; offer to do.
UNDISCOVERED: not found.
UNDOUBTEDLY: without doubt; certainly.
UNFORTUNATELY: unluckily.
UNLIMITED: limitless.
UNMANAGEABLE: which cannot be controlled.
UNMIXED: pure.
UNQUESTIONED: not doubted.
UNSOUND: incorrect.

UNTIRING: not getting tired; continuing.
UP-TO-DATE: modern.
URANIUM: a heavy and rare metal.
UTENSIL: thing for cooking food in.

VACCINATION: the action of scratching the skin and putting the germs of cowpox on the scratch.
VACCINE: the material used for vaccination.
VACUUM: a space without air.
VALVE: thing which allows steam, electricity or gas to pass through in one direction.
VAPORIZE: turn into gas.
VAPOUR: gas.
VARIED: different.
VAST: very big.
VEGETABLE: plant used for food.
VEHICLE: any kind of carriage.
VEIN: tube in the body which carries blood to the heart.
VENTILATION: the providing of fresh air.
VESSEL: ship.
VICTIM: a person who suffers; an animal which suffers.
VIGOROUS: strong and active.
VITAL: necessary to life.
VITAMIN: substance necessary to health, and found in fresh fruit, leaves, etc.
VOLTAGE: pressure of electricity.

WAGGON: cart; thing to carry goods.
WARFARE: the act of making war.
WASH UP: wash the dirty plates and dishes.
WELFARE: health and happiness.
WELL OFF: rich.
WELL-TO-DO: rich.
WHALE: the largest sea creature.
WIDESPREAD: spread widely; common.
WIRELESS SILENCE: absence of radio messages.
WIRING: all the wires.
WITH A VIEW TO: with the aim of.
WITHSTAND: stand against.
WORK OUT: work at, until the answer is found.
WORKSHOP: works; place where goods are made or mended.
WORLD-WIDE: covering the world; found all over the world.

1.05

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